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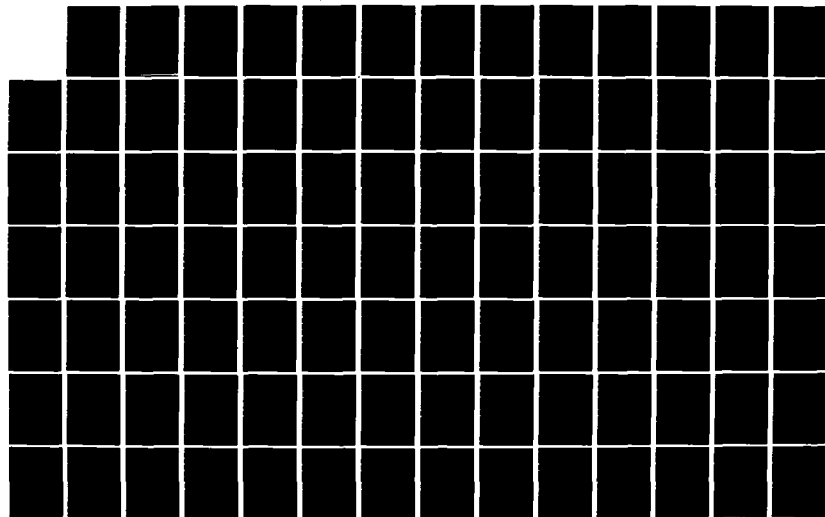
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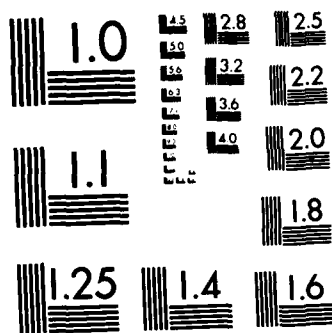
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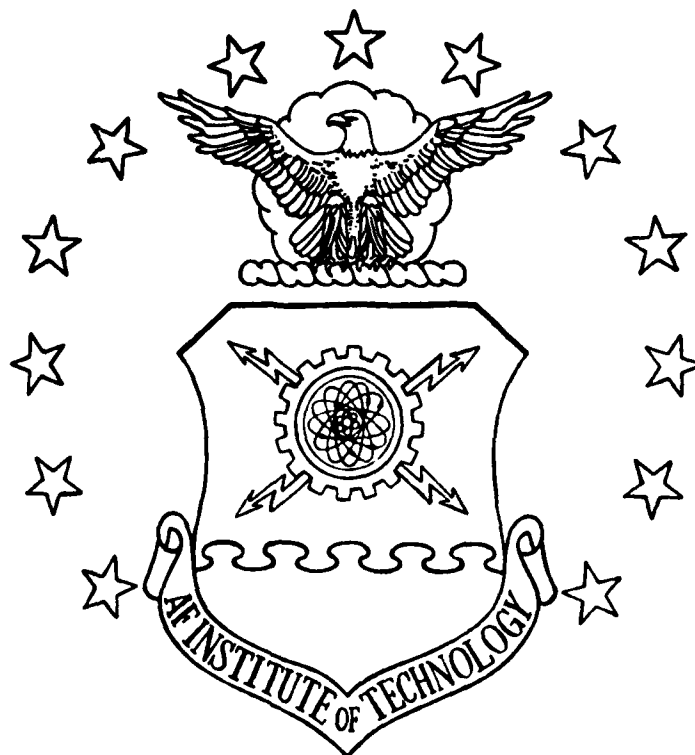
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AIRCRAFT CONTRACTOR LOGISTICS
SUPPORT: A COST ESTIMATING GUIDE

Eilanna S. Price, GS-12

LSSR 9-83

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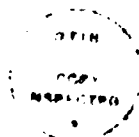
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The Air Force has used Contractor Logistics Support (CLS) for off-the-shelf or commercial derivative aircraft since 1948. This thesis traces the evolution of CLS, discusses the current USAF aircraft utilizing this support concept, and compares eight CLS contracts. An aircraft characteristics data base is developed for the E-4, C-9A, C-12A, T-43, KC-10, UV-18B, T-41, and C-20A. CLS contract costs are used as a dependent variable to provide an example of a parametric procedure that can be used to estimate CLS costs on proposed aircraft. Analogy as an alternate procedure is suggested. Recommendations on improving the CLS cost estimating in the future are presented.

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AIRCRAFT CONTRACTOR LOGISTICS SUPPORT:
A COST ESTIMATING GUIDE

A Thesis

Presented to the Faculty of the School of Systems and Logistics
of the Air Force Institute of Technology

Air University

In Partial Fulfillment of the Requirements for the
Degree of Master of Science in Logistics Management

By

Eilanna S. Price, BA
GS-12

September 1983

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has been accepted by the undersigned on behalf of the
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CHAPTER I

INTRODUCTION

Overview

Approximately half of the Department of Defense budget is now used for Operating and Support expenditures (46:29). This has caused increased management attention of this area as evidenced by cuts in the flying hour programs, authorized aircraft, and authorized personnel. To help control these operating and support costs, the Air Force Acquisition Logistics Division and the Aeronautical Systems Division/Life Cycle Cost Support Division were created. Their task is to assure that a systems life cycle cost is properly considered in acquisition when much of the ultimate operating and support cost is designed in.

Life cycle cost refers to the total cost of a weapon system. This includes research, development, procurement, operation, support, and disposal costs. On a systems level, Operating and Support costs are now the major portion of an aircraft system's ultimate cost, around 60 percent (46:29). Operation and support of Air Force weapon systems has traditionally been organic; i.e., operated and supported by blue suit and civilian employees. Contractor Logistics Support (CLS) developed as an alternative. CLS

occurs when a contractor (commercial organization) performs part or all of the operating and maintenance support for a weapon system, for the life of that weapon system.

Problem Statement

There is no guidance in constructing a CLS cost estimate for an aircraft.

Background

The Army, Navy, and Air Force have utilized commercial logistics support since World War II. The Army began in 1939 with complete contractor logistics support (CLS) of pilot training operations to support in-house capability. The Army Air Corps could graduate only 500 pilots a year from in-house flight training and with greater demand for more pilots, faster training was needed. Contractors provided not only full maintenance but pilot training as well. By 1944 the Civilian Flying Schools trained 81,024 pilots which allowed the United States to build an air force quickly. This surge capability also allowed military personnel to be assigned to combat functions. Results were outstanding and the Army has used CLS in their pilot training programs ever since; both for economy and flexibility (8:18-20).

The Army has also used CLS in non-pilot training missions. Fort Rucker is the Army's major training base with 600 helicopters (six different types) and twelve

aircraft (three types) being cleaned and maintained by Northrop (except for flightline operations). Northrop is on contract twenty-four hours a day, seven days a week. Another contractor, Epts, is responsible for fueling and defueling aircraft at all three airfields and twenty landing sites. The General Services Administration buys and delivers the fuel to the contractor at Fort Rucker. A third contractor, Aviation Contractor Employee's, Inc., provides pilots for primary phase pilot training. Fort Rucker will spend fifty-five to sixty million dollars in 1983 on services from these three contractors. Army personnel, Air Force personnel, Coast Guard personnel, treasury agents, and foreign students are trained at Fort Rucker. Two Contract Officer Representatives are used by the Army to monitor contractor performance. Contractor services have been utilized at Fort Rucker for the past twenty years due to the inherent flexibility and diversity it provides. Although there have been several changes in contractors, no major problems have developed (27; 28).

The Navy started with CLS using contractor maintenance at the depot level following World War II. The success of contracting depot maintenance on the C-121 in the early 1950s led to depot contracts on six other aircraft. The Navy has also maintained in-house depot capabilities for training reasons. Beginning in 1958 new aircraft systems utilized not CLS but Interim Contractor

Support to phase in organic maintenance concepts. The first CLS contract was awarded on the TC-4C electronic trainer for the A-6 aircraft in 1966. The contractor, Grumman, was responsible for the airframe while the government still supported the avionics. Although interface problems existed, the program demonstrated the advantages of CLS. In 1967 the CT-39E/G special trainer employed CLS with Rockwell International Corporation for all but organizational maintenance. The only government furnished equipment on this aircraft was a Navy UHF and a TACAN. FAA regulations were used as work standards to keep from overspecifying requirements. The TH-57A undergraduate training helicopter followed in 1968 with a Bell Helicopter Company CLS contract. The Navy's C-9Bs delivered in 1973 were supported by McDonnell Douglas, including organizational maintenance. Up through this point all organizational maintenance had been done by the Navy with the contractor responsible for all other maintenance. The first Navy program to have total CLS was the T-44A multi-engine trainer which entered the inventory in 1977. As this discussion shows, aircraft chosen by the Navy for CLS application are trainers or small fleets of cargo/transport aircraft with no combat missions (8:25-33).

Today the Navy has CLS contracts for 60 T-44s, 290 T-34s, and is contemplating CLS on the TH-57 helicopter and the T-2 trainer. Unlike the Army and Air Force,

the Navy CLS contracts are sole source contracts. All of these systems are used for training by Navy Air Training Command and the contractor does all maintenance. The contracts are set up with four line items. Line item one is for direct level work including squadron maintenance, proposed inspections, and all on-aircraft maintenance. The second line item covers on-site support made up of overhead, computer services, maintenance tools, and direct manufacture. Line item three includes material with a provision based on flying hours with add-on rates specified for material and maintenance if the agreed-to flying hour program is overflowed. Line item four is for depot work. A major difference from the Army contracts is that the Navy negotiates an annual cost per line item with monthly and quarterly progress payments, while the Army negotiates pay for work done. Also, no incentive clauses are included in the Navy contracts (16).

Contracting out of maintenance services began in the Air Force in 1948 due to the Berlin blockade. The increased airlift requirements of Berlin led to depot maintenance commercial contracts. The depot contracts were for cargo aircraft which had civilian versions being supported. The success of these contracts resulted in further contractor depot maintenance until 1957 when 54 percent of the depot workload was contracted out. Today a steady level of 60 percent of depot work is performed by commercial

organizations. Total CLS came in 1951 when civilian contract flying schools, such as the Army had operated, were used for pilot training. It should be noted that the pilot training and the logistic support for the training operations were both contracted. The schools were again successful, utilizing fewer people than if run organically. Due to the high skill level of contractor personnel, CLS was also very flexible in accommodating equipment updates and modifications at the base level. In addition to meeting all operational readiness criteria, the training operation had a clean safety record with no aircraft accidents caused by aircraft maintenance error (8:22-23).

The cost advantages of CLS were recognized by comparing in-house pilot training to the civilian contract flying schools. In a move to reduce in-house pilot training costs to comparable levels, Air Training Command contracted out all maintenance and service operations with Serv-Air, Inc. at Vance Air Force Base in July 1960. Flight instruction was kept as an in-house function but civil engineering and transportation were part of the contract. Vance operations are a showcase of cost savings. In 1974 Serv-Air, Inc. showed a 2.2 million dollar savings in that year alone compared to Air Force organic operations at Reese AFB for similar services. Cost savings are accounted for by Serv-Air using 35 percent fewer people

than a similar organic operation, while performing work to Air Force specifications (8:24,56).

Just as the Navy uses CLS for off-the-shelf aircraft, the Air Force began using CLS as an aircraft (not base) maintenance support concept in 1967 with the C-9A and has continued to this date. McDonnell Douglas, as the contractor, provides all intermediate and depot maintenance as well as all supply functions. Organizational level maintenance is still performed by Air Force personnel (8:24). The concept has worked well and has since been applied to the C-12A, E-4A, T-43, T-41A/C, C-20A, UV-18B, and the SR-71 (22:23).

To better understand the Air Force CLS concept a brief overview of one Air Force CLS system follows.

A very recent application of CLS in the Air Force is on the KC-10 program begun by Douglas Aircraft Company in March 1981. Besides economics, a major reason for going CLS on the KC-10 was the increased support from the current DC-10 (the commercial aircraft) worldwide logistics infrastructure. This infrastructure includes a large strategically placed spares inventory, a worldwide distribution system, an established network of maintenance bases, and a communications system. The advantages of using an in-place, proven, worldwide logistics support system are increased support, reduced risk, and reduced cost (22:56-62).

The KC-10 CLS contract has six elements:

1. The planning or preoperational period.
2. The initial lay-in of spare parts and support equipment.
3. Main Operating Base activation.
4. A Firm Fixed Price (FFP) per flight hour maintenance cost.
5. A fixed cost of operating and maintaining base activities (at specified aircraft levels).
6. An over and above option for flexibility in covering work not included in the other sections (2:11-49).

The first element was part of the basic contract signed in January 1978 and was FFP. The second through fifth elements were individual options with economic price adjustments and were written with yearly options. Several contract amendments have occurred because specific aircraft numbers at specific main operating base locations were part of the options and have changed. The third option covers a fixed price over 1200 flying hours for intermediate and depot level maintenance and replenishment spares. After aircraft delivery, the specified flying hour program did not provide enough flexibility. A contract amendment was made to include a flying hour matrix with FFP on intervals of flying hours. This allowed typical military base operations to continue without breaking CLS contract provisions. The sixth element was an unpriced line item to cover over

and above work. As a contractual vehicle this allows negotiation for contingency type work on an as-needed basis. On-site crash damage repair by a contractor field team is an example (2:11-49).

While the structure appears very loose, the contract specifies performance characteristics. The contractor must meet a launch reliability of 96 percent, 70 percent daily operations, 80 percent surge full mission capable rates and a 90 percent contingency/special mission availability after notification. Experience so far has been excellent (2:11-49).

Examples of how CLS costs have been estimated are shown by the Tanker Trainer Bomber and the European Distribution System studies. Once a need has been established for a new aircraft system and the aircraft is a candidate for a CLS maintenance concept (off-the-shelf aircraft, small fleet size, and no combat mission) a tradeoff analysis is performed. The tradeoff studies for the Tanker Trainer Bomber and the European Distribution System were handled with the same methodology during the first quarter of 1982. The tradeoff was between a standard organic, three level, maintenance concept and a CLS maintenance concept. A twenty-year O&S cost was developed for the proposed trainer via standard methods before any RFQ or RFP. Using the analogous method, a similar aircraft was used to build an organic estimate using the Cost Oriented Resource Estimating

(CORE) model. The similar aircraft was the T-37. As with other training systems, organizational maintenance is done by the Air Force. To simplify the study all work that would continue to be done by the Air Force was eliminated. This included organizational level maintenance, organizational level manpower, petroleum oil and lubricants (not usually part of a CLS contract), aircrew costs, and class IV (safety of flight) modification costs. To make a comparable estimate with similar CLS contracts, the cost of initial spares, facilities, technical data, and support equipment were added in. The resulting level of effort and materials corresponds to the KC-10 CLS contract coverage. The KC-10 contract costs were then adjusted by a flyaway cost ratio, an aircraft ratio, and flying hour ratio since the aircraft would have different missions. Finally, all costs were put in 1982 dollars (42:1-5).

Since the Tanker Trainer Bomber (outside of a mission) was not yet specified, several options were run based on realistic differences expected from the T-37, such as lower maintenance manhours per flying hour. In all options the CLS cost was between 50 and 60 percent of organic costs for comparable services. The organic versus CLS tradeoff study for the EDS applied the same procedure (42:1-5).

Estimates of CLS contracts are needed for other decisions as well. The KC-10 has already been fielded,

but in July 1982 a new organic versus contractor support cost study was requested by HQ SAC/LG due to a change in the initial study assumptions. The aircraft utilization rate had increased and was projected to double along with a projected increase in fleet size from sixty to eighty-four aircraft. The study was to determine the fleet size at which it would become more cost effective to maintain the KC-10s organically rather than with CLS. The KC-10 CLS contract costs were used against a comparable organic effort as estimated by the CORE model with organizational level maintenance and manpower omitted. Separate initial spares, technical data, and facilities were added to the organic estimate for comparability. The results showed a fleet size of around 320 aircraft needed for an organic support concept to be as cost effective as CLS. The continual changes in aircraft systems require updated analysis as assumptions change (23:1-39).

Justification

The increased use of CLS in the Air Force is driven by many independent occurrences. These include: increased acquisition time for new aircraft, a declining industrial base, a requirement for faster response to a crisis situation, policies for acquiring commercial or industrial products and services needed by the government, and increased off-the-shelf aircraft purchases. CLS has clear

advantages in each of these cases as the following discussion illustrates. As CLS strategy becomes more common, a cost estimating methodology for use in the competitive source selection process becomes imperative.

Acquisition Time

For DOD the length of time required to develop and produce a new aircraft has increased in average length from five to seven years, following World War II, to twelve to fifteen years today. In comparison, the Boeing Company today only requires four years to develop and produce a new aircraft. One reason for their shorter acquisition time is that commercial aircraft use existing technology, while most military aircraft push the state of the art in technology. When CLS is a feasible support alternative, acquisition time can be shortened since the Air Force does not have to develop and procure a support system. CLS has only been used on "ready-for-production" aircraft where the military does not push the state of the art (33:3,6-7).

Declining Industrial Base and Crisis Response Time

Two related problems can also be addressed by applying CLS. The industrial base of the United States has declined to the point where reliance on a quick industrial surge to support a military crisis has become questionable. The total number of defense manufacturers has decreased

while lead times have continued to increase. A greater application of CLS with off-the-shelf or modified commercial equipment would help due to commonality with the commercial sector. Support in times of crisis would be aided by commercial supplies already available (43:46; 44:29-33).

Policy for Acquiring Commercial or Industrial Products and Services

The government policy is contained in OMB Circular A-76, "Policies for Acquiring Commercial or Industrial Products and Services Needed by the Government." In addition to policy, it contains a cost comparison analysis process for acquiring commercial or industrial products and services (30).

In general, the policy is that all work which can be done cheaper commercially will be contracted out, except that the Department of Defense (DOD) is exempted from contracting out work (such as intermediate and depot maintenance) required to meet national defense needs. Training and eventual combat support can also be reasons for exempting work from the requirement to determine if contracting out is more cost effective (30:3-7). Because of OMB Circular A-76 policy, a Congressional Budget Office (CBO) study indicated a 150 percent increase in service contract awards for nondefense government agencies from 1979 to 1981 and for the same time period the DOD had a

113 percent increase in service contract awards (12:7). CLS is a type of service contract currently being used by the Air Force on the C-9A hospital aircraft, the E-4 airborne command post, the C-12A special transport aircraft, the T-43A undergraduate navigator trainer, the KC-10 tanker/cargo aircraft, the T-41A/C pilot trainer, and the UV-18B AF academy trainer/parachute jump aircraft.

Increased Off-the-Shelf Purchases

Several upcoming Air Force aircraft acquisition programs have CLS in their acquisition strategy. These are the Tanker Trainer Bomber (TTB), a small aircraft designed to handle as a bomber or a tanker for specialized pilot training as a fuel conservation measure; the European Distribution System (EDS) aircraft, part of a new European theatre logistics system to ferry parts; the Special Airlift Mission (C-20A), a new presidential plane; and the Operational Support Aircraft (OSA), a special mission aircraft. CLS is a viable logistic support strategy that will have increasing applications in the future.

CLS solves some military support problems and its use as a support strategy is increasing. CLS can help shorten acquisition time, provide more business for a declining defense industrial base, and increase crisis response time through commonality with the commercial sector. CLS follows current government policy on acquiring

commercial services and its increased application is seen in the four upcoming Air Force acquisition programs. The increased trend of using CLS highlights the need for a logical cost-estimating methodology for CLS.

Research Objective

General

The general objective of this research is to investigate relationships between aircraft CLS costs and aircraft parameters to develop an improved methodology for CLS cost estimates.

Specific

1. Document the CLS contract structure of existing Air Force CLS contracts (C-9A, C-12A, T-43, E-4A, C-20A, UV-18B, T-41A/C, and the KC-10 aircraft).
2. Identify a cost element structure which can encompass current CLS contract applications.
3. Describe a methodology, algorithm, or cost-estimating relationship (CER), for each element of the cost element structure.
4. Document cost categories encompassed by O&S costs but outside the CLS cost element structure.

Research Questions

1. What are the similarities and differences in CLS for the current CLS contracts?

2. What are the CLS contract line items or option structure of current CLS contracts?

3. What are the costs on each line item or option, baselined in 1983 dollars, for the current CLS contracts?

4. What line items are common to all CLS contracts?

5. Would parametric techniques be useful in CLS estimating; i.e., is there a cost relationship for common line items between current CLS contracts?

CHAPTER II

METHODOLOGY

Overview

Cost estimates can be developed using several different methods. The major categories of methods are expert opinion, analogy, engineering, and parametric. Using expert opinion as a source for a cost estimate is appropriate if historical information is not available to use the other three methods, if time does not allow for implementing the other methods, or as a means to verify other estimates. For this effort, time and available data do permit consideration of the other methods. Due to the difficulty in defining what a CLS expert is, and the difficulties in properly documenting such an estimate, the expert opinion method is inappropriate for this effort (14:4-2).

Analogy is a method of using known costs of a similar system as a basis to estimate the costs of a new system. Differences between the two systems are identified and the estimate is adjusted to reflect the anticipated changes. Analogy is a practical method if a similar system exists and data is available. This method was used in the Tanker Trainer Bomber and European Distribution System study even though the KC-10 was very different in size

and level of technology. Since the analogy method is the current procedure, this method will be kept as a fallback position if better methods cannot be applied (13:4-1,2).

The industrial engineering method uses actual standards or costs of measurable work units (i.e., man-hours) to build a grass roots cost estimate. The discrete tasks needed to perform the work must be identified for all functional areas. In addition, the exact amount of labor and type of material needed to perform the tasks must be identified to develop standards. Worker efficiency and changes over time must also be known. Clearly, the Air Force limited experience with CLS has not established any such standards and the inability to retrieve this detailed information from the CLS contractors makes the industrial engineering standards method inappropriate for this effort (13:4-2).

The final method, parametric cost estimating, uses system characteristics or costs to develop a cost-estimating relationship (CER). First, the dependent variable and a set of potential independent variables are defined. Data is then collected on these variables and statistical analysis performed to determine the CER that best describes the data. Scatter diagrams and correlation coefficients between the variables help determine the independent variables to use. Due to the nature of available data and the

availability of several Air Force aircraft supported by CLS, the parametric cost-estimating method will be used for this effort (13:A-3,1,5).

Research Questions 1, 2, and 3

All current aircraft CLS contracts will be collected and analyzed. A summary grid chart will be developed to consolidate information on contract line items across contracts. Similarities and differences between contracts will be highlighted.

Research Question 4

While the term cost will be applied here to refer to line item prices, a difference does exist. The ideal situation would be to have actual costs of providing CLS services to specific aircraft type. But, this type of information is proprietary and unavailable for analysis. The remaining alternative is to use contract line item prices as the dependent variable in place of actual costs. While predicting actual costs on a new CLS aircraft is preferable, predicting contract costs is still useful since this is what the government must budget for and obligate.

Each line item cost will be normalized to a common unit (per aircraft, per flying hour). All costs will then be inflated to fiscal year 1983 dollars so comparisons can

be made. The published OSD inflation rates currently in use at the time of analysis will be used.

Research Question 5

To answer research question number 5 and determine cost estimating relationships (CERs), least squares regression will be used as the statistical technique. The dependent variable (Y) is cost and the possible independent variables (X_i) will include: aircraft unit flyaway cost, combat weight, empty weight, gross maximum takeoff weight, maximum thrust per aircraft, intermediate thrust per aircraft, maximum continuous normal thrust per aircraft, nautical miles flown per pound of fuel, maximum speed in knots, and average cruise speed.

Cost data points will come from the KC-10, C-12A, C-20A, UV-18B, T-41A, C-9A, T-43, and the E-4A CLS contracts. Since a series of contracts have been let over time for most of these aircraft, the most recent CLS contracts on each aircraft will be utilized and adjusted to base year 1983 dollars. Since the data base aircraft include jet, turboprop, and reciprocating engines, a conversion formula will be used. The Navy and Army aircraft will not be included as data points due to different mission profiles and different contract structures. This effort is limited to Air Force CLS aircraft only. The SR-71 will not be included since the data is classified.

Least squares regression analysis will be used to illustrate how a CER for yearly CLS costs based on aircraft characteristics could be developed (25:458). The cumulative result will be guidelines for a CLS estimate, given basic aircraft characteristics (the independent variables).

The limited number of data points being utilized for this regression is due to a small population. There will be eight data points with at most five independent variables, since some of the highly correlated independent variables will be dropped. However, with the acquisition of the TTB, EDS, OSA, C-18, and C-19 anticipated, a guide to estimate CLS is needed now. In view of the defense dollars to be spent on new CLS contracts, the use of regression analysis on such a small population is justified. This procedure is to provide a guide to CLS cost estimating until a larger data base becomes established to generate a more stable model. Models using this methodology should be extremely useful in carrying out tradeoff studies on organic versus CLS support concepts. As more data points become available (additional CLS contracts on different aircraft), least squares regression should be redone.

CHAPTER III

USAF CONTRACTOR LOGISTICS SUPPORT AIRCRAFT

Overview

This chapter is organized by aircraft. Each aircraft is briefly described and then an overview of the CLS contract for that aircraft is presented. Detailed contract descriptions are found in Appendix A. Contracts are described by line item to facilitate referencing for Chapter IV's research questions. The aircraft presented are: E-4, C-9A, C-12A, T-43, KC-10, UV-18B, T-41C, and the C-20A.

Aircraft Synopsis

E-4

The USAF E-4 is built by Boeing with a commercial designation of 747. The first flight of the 747 was 9 February 1969. By October 1980, 467 had been delivered. The E-4s were delivered to the Air Force between 1974 and 1976. The E-4 has four General Electric CF6-50E turbofan engines. Landing gear is hydraulically-retractable tricycle type. The 747 aircraft can accommodate 452 passengers with a crew of three. The space inside the E-4 is divided into six areas (40:292-293).

Intermediate and depot level maintenance on the USAF E-4s is provided by the Boeing Company. Options allow CLS coverage to continue through fiscal year 1987. The ten contract line items are: Contractor Operated and Maintained Base Supply (COMBS) operation, spare parts repair/replenishment, contractor field representatives, bench stock, data, parts, transportation charges, additional spares, spares maintenance/modifications, emergency repair, and specific over and above authorized work (3:1-5).

C-9A

The USAF C-9A was built by McDonnell Douglas Corporation with a commercial designation of DC-9. The first flight of the DC-9 was on 25 February 1965. As of July 1981, 984, including the military versions had been delivered. The USAF received twenty-one C-9As between 1968 and 1973 to be used for aeromedical airlift transport. The C-9A is a twin turbofan short/medium range aircraft. Landing gear is retractable tricycle type with steerable nosewheel. The C-9A is an off-the-shelf DC-9 series 30 aircraft with two JT8D-9 engines. It carries thirty to forty litter patients or more than forty ambulatory patients with two nurses and three aeromedical technicians. The interior has a special-care compartment, with separate atmospheric and ventilation controls, and two galleys (41:408).

The C-9A CLS contract with Douglas Aircraft Company supports three C-9A aircraft for all maintenance and repair except for flightline, which is to be done by the using command. The remaining USAF C-9s are supported by other means. The nine contract line items are: Programmed Depot Maintenance (PDM), Contractor Operated and Maintained Base Supply (COMBS) operation, support equipment maintenance, maintenance support technicians, bench stock, data, over and above work, and Service Bulletin/Service Change Kits. Yearly options allow for CLS to be continued (5:1-10).

C-12A

The C-12A is a Beechcraft aircraft with a commercial designation of Super King Air 200. The first production aircraft flew in June 1973 and the first C-12A was delivered to the United States Air Force in December 1974. As of 1 January 1980 Beechcraft had built 717 Super King Air 200 aircraft with 117 designated C-12s and in use by U.S. military services. The Super King Air 200 is used as an air ambulance, commuter aircraft, cargo transport, and used for natural desert resource exploration, maritime patrol, and border patrol. A modified version (200T) is used for high-altitude photographic and weather observation missions. The C-12A seats two pilots, eight passengers, and has easy conversion for a cargo compartment. The C-12A

is powered by two PT6A-38 turboprop Pratt and Whitney (of Canada) engines. The engines drive a Hartzell three-blade constant-speed fully feathering reversible pitch propeller (40:276).

The C-12 CLS contract with Beech Aerospace Services, Inc. provides for organizational, intermediate, and depot level maintenance for twenty-nine C-12A aircraft on a world-wide basis. The contract has the following ten contract line items: logistic support for a specified flying hour program, cost on a per flying hour basis for additional hours, custom charges on parts importation, over and above work, collision damage, aircraft modifications, aircraft relocation, contractor technicians temporary duty (TDY), over and above material, and data (1:1-5).

T-43

The USAF T-43A is a modified Boeing 737-200. The first flight of the 737 was 9 April 1967 and by 6 August 1981 779 had been delivered. The T-43A is powered by two Pratt and Whitney JT8D turbofan engines in underwing pods. Landing gear is hydraulically-retractable tricycle type with free-fall extension. Accommodations allow for 115 passengers (convertible to cargo), a pilot and copilot (41:306-307).

The USAF F-43As are supported by Boeing Aerospace Company for intermediate and depot level maintenance. The

ten contract line items are: Programmed Depot Maintenance (PDM), engine maintenance, COMBS operation, support equipment maintenance, field service personnel, bench stock, over and above for contingencies, over and above fair wear and tear, data, and service bulletin modifications (4:1-7).

KC-10

The USAF KC-10 extender is a military version of the McDonnell Douglas Corporation DC-10 series 30 convertible freighter. As of 11 August 1982, ten KC-10As had been delivered to the Air Force. Modifications to the DC-10 include additional fuel cells, a boom operator station, an aerial refueling boom, a refueling receptacle, an improved cargo handling system, and military avionics systems. The DC-10's first flight was 29 August 1970 and by June 1982 362 DC-10s had been produced. The DC-10-30CF is an extended range commercial transport with three CF6-50C turbofan engines. Landing gear is hydraulically-retractable tricycle type with an additional dual-wheel main unit on the fuselage centerline. The aircraft is designed for a crew of three with two additional observers and 380 passengers. The series 30CF is easily convertible overnight to a cargo configuration (41:412-413).

The USAF KC-10 CLS contract with McDonnell Douglas Corporation includes all intermediate and depot level maintenance. As the first KC-10 CLS contract, scheduled

aircraft deliveries may vary. Line items must consider a variable level of effort to accommodate varied aircraft deliveries. The ten contract line items are: preoperational planning, data, over and above work, investment material, site activation, maintenance and replenishment material, COMBS operations, recurring data, retrofit kit installation, and delivered retrofit kits (2:1-5).

UV-18B

The UV-18B is a short takeoff and landing aircraft with two PT6A-20 Pratt and Whitney turboprop engines. Built by de Havilland of Canada and called the Twin Otter, its commercial designation is DHC-6. The first production version flew on May 20, 1965. As of February 1981, 720 Twin Otters had been produced. The UV-18B seats two pilots and twenty passengers. The landing gear is a non-retractable tricycle type. The engines drive a three-blade reversible-pitch fully-feathering metal propeller. The Twin Otter is a utility aircraft that is used elsewhere as a maritime surveillance aircraft, a photo survey aircraft, a floatplane, a commuter aircraft, and a cargo aircraft. The USAF owns two, operated at the U.S. Air Force Academy as a parachute jump ship and a pilot trainer for cadets (39:24-25).

Ross Aviation, Inc. provides CLS support for the USAF UV-18Bs including all organizational, intermediate,

and depot level maintenance. The four contract line items are: normal organizational, intermediate, and depot level maintenance and service excluding engine overhauls; engine overhaul/remanufacture; labor for over and above repairs; and material for over and above repairs (6:1-9).

T-41C

The T-41C/D Mescalero is built by Cessna and designated R172E commercially. The first production model was completed in 1964 and the USAF received the first T-41C in 1967. The T-41C has one Continental IO-360-D flat six engine which drives a constant-speed propeller. Landing gear is the nonretractable tricycle type. A total of 30,654 Model 172 aircraft had been built as of January 1979 including those built in France by Reims aviation. The Air Force has bought fifty-two T-41Cs (40:308).

Doss Aviation, Inc. CLS contract for the USAF T-41Cs, at Randolph AFB, provides for organizational, intermediate, and depot level maintenance along with all Petroleum Oil and Lubricants (POL). The contract has nine line items, eight of which specify a firm fixed price per flying hour, differentiated by the type of flying (i.e., pilot instructor training). Operation and maintenance for the required flying hours is covered in a separate line item (7:1-3).

C-20A

The C-20A is a derivative of the Gulfstream Aerospace Corporation, Gulfstream III. Primary differences from the C-20A and Gulfstream III are an expanded communications capability for the passengers (including secure voice and SATCOM), a flat plate bulkhead, APX-100, forward and aft lavatories. The Gulfstream III's first flight was on 2 December 1979 with FAA certification in September 1980. The Gulfstream III is a twin-turbofan executive transport with retractable tricycle type landing gear. Two pod-mounted Rolls-Royce Spey Mk 511-8 engines power the aircraft. The C-20A accommodates fourteen passengers and a crew of five (41:87-88).

The USAF C-20A is a new aircraft to be produced by Gulfstream and supported by E-Systems. CLS provides for intermediate and depot level maintenance. The six sub-line items which cover CLS are: COMBS operation, contractor field service, aircraft maintenance, depot maintenance, logistic data, and peculiar support equipment (17).

Summary

The E-4, C-9A, C-12A, T-43, KC-10, UV-18B, T-41C, and the C-20A are all small fleets of aircraft supported by CLS. Each of these aircraft is a commercial off-the-shelf aircraft with minor modifications. While the USAF fleets are small, the number of commercial aircraft is high.

The aircraft are either special mission aircraft (E-4, C-12A, and C-20A), trainers (T-43, UV-18B, and T-41C), or modified cargo aircraft (C-9A medical airlift and the KC-10 tanker/cargo). None of these aircraft has combat missions and except for some specialized E-4 modifications these aircraft are not pushing the state of the art in technology. The aircraft cover a wide range in size, technology, missions, and aircraft characteristics but all are supported by CLS.

CHAPTER IV

RESEARCH QUESTIONS 1, 2, 3, AND 4 ANSWERED

Research Question 1

1. *What are the similarities and differences in CLS for the current CLS contracts?*

Similarities between the CLS contracts for the C-9A, C-12A, T-41, T-43, UV-18B, E-4, KC-10, and C-20A will be described first followed by the major differences among the contracts. Similarities include provisions for over and above work, yearly options, and government-provided facilities. All eight contracts have provisions through line items or special clauses for over and above work to be performed. Since all contingencies cannot be defined or their frequency anticipated, over and above work encompasses all non-routine contractor services which might be required. In all cases the over and above work must be authorized by a Principle Contracting Officer (PCO) or his authorized representative and a price negotiated as the need for services arises.

In addition, all eight CLS contracts contain separately priced line items or options to extend CLS coverage. All contracts are set up in fiscal year increments with provisions of at least a total (including the

original contract year) of five years of CLS coverage. Note this implies a sole source contracting position, but the prices for these basic services (not over and above) are firm fixed prices.

The last major similarity is the allowance for use of government facilities. Each contract specifies some sort of government facility or covered space will be provided on or near the operational base for COMBS type operations. These facilities are free of charge and usually a specified number of square feet of floor space. In all but one contract (C-20A), a limited amount of office furniture is also provided.

Although the C-9A, C-12A, T-41, T-43, UV-18B, E-4, KC-10, and C-20A are all supported by CLS, most of the contracts have provisions which differentiate the services provided. Differences include the level of maintenance covered (organizational, intermediate, or depot level), POL, T-41 priced by type of flying hours, C-12A and UV-18B specified flying hour program, the KC-10 flying hour matrix, and provisions for changing over to an organic maintenance concept. A major division among the contracts is the level of maintenance coverage. The C-12A, T-41, and UV-18B have CLS contracts which cover organizational, intermediate and depot level maintenance. The USAF basically flies the aircraft while the contractor does everything else, including pre-flight/post-flight inspections. The C-9A, T-43, E-4,

KC-10, and the C-20A only have CLS for intermediate and depot level maintenance. While the CLS coverage is different, the UV-18B and T-41 are used for training and the intermediate and depot level maintenance on these relatively simple aircraft is anticipated to be less than more complex aircraft like the KC-10, E-4, the specialized C-20A, C-9A, and the T-43. The C-12A has a unique mission and no additional personnel were anticipated in providing the organizational level maintenance requirement.

The T-41 has a unique contract due to POL provisions and the contract line-item structure. Rather than separate out material and maintenance support, the T-41 contract rolls up all CLS costs (except a monthly charge) into a cost per flying hour based on the type of flying being done. The charge thus depends on whether cross-country or pilot instructor training is being done. Further, the POL is provided by the contractor unlike the remaining seven CLS contracts where all POL is government furnished. The price per flying hour of fuel and oil is specified so the cost can be deducted from the price per flying hour to determine a comparable services price with the other seven contracts.

The C-12A and UV-18B contracts are different from the other CLS contracts because a per flying hour charge is not specified. Instead, the contracts are written for a specified number of flying hours with a narrow plus or

minus margin. Both systems have been used by the Air Force for a number of years and the CLS contracts have been recompeted. System managers of both aircraft expressed no problems with a contract to cover a fixed flying hour program.

The KC-10 is a new aircraft still in production and under the original CLS provisions. The problems of fielding a new system results in a large variance in flying hours from month to month. To solve the differences in work associated with this variable flying hour program, the KC-10 has a flying hour matrix which specifies a fixed price per flying hour when the utilization rate is within one of eight ranges, from .7 flying hours per aircraft per day to 3.33 flying hours per aircraft per day. Such a flexible approach to the work load generated by a changing flying hour program has worked well for the users of the KC-10.

The final difference to be noted is a provision found in the C-12 and T-43 CLS contracts which allows the government to change over to an organic maintenance concept, at the government's discretion. These are more than termination clauses and specify property turnover, training required, and contractor responsibilities for an interim period to the government. It is worth noting that the contract for the newest aircraft to have CLS, the C-20A, specifically excludes such a provision.

The C-9A, C-12A, T-41, T-43, UV-18B, E-4, KC-10, and C-20A CLS contracts all have over and above work provisions, yearly options to continue CLS, and government provided facilities. Differences include: intermediate and depot level maintenance versus organizational, intermediate, and depot level maintenance; contractor provided POL for the T-41 aircraft; a price per type of flying hour on the T-41; the KC-10 flying hour matrix; the C-12A and UV-18B contracts with a specified flying hour coverage; and provisions for changing to an organic maintenance concept. Research question 4's answer will show specific line item differences between the contracts.

Research Questions 2 and 3

2. *What are the CLS contract line items or option structure of current CLS contracts?*

3. *What are the costs on each line item or option, baselined in 1983 dollars, for the current CLS contracts?*

Both research questions 2 and 3 are answered in the Tables 4-1 through 4-8. Each table is for a particular aircraft and lists the CLS contract line items, applicable yearly prices, inflation rates and 1983 prices if necessary, and a per flying hour, per aircraft, or per month charge for yearly CLS options. Additional explanations of the contract line items can be found in Appendix A contract overviews. Inflation rates are from AFR 173-13, dated 1 February 1983.

TABLE 4-1
E-4 CONTRACT SUMMARY (3) (a)

CLIN	Line Item	Base Year 1983 \$
0001	COMBS	3,280,000.00
0002	Repair &/or Replen of Spare Parts	1,920,000.00 Est.
0003	Field Support Personnel	655,841.00
0004	Bench Stock	55,000.00 Est.
0005	Data (in CLIN 0001)	
0006	Transportation of Spare Parts	252,000.00 Est.
0007	Additional Spares	3,000,000.00 Est.
0008	Spare Parts Maint	20,000.00 Est.
0009	Emergency Repair & Mission Essential Unscheduled Maint	20,000.00 Est.
0010	Over and Above	1,501,159.00 Est.

(a) For four aircraft.

TABLE 4-2
C9-A CONTRACT SUMMARY (5) (a)

CLIN	Line Item	4th Year Renewal Period 1983 \$
0001	PDM	As neg by the ACO
0001 BA	Eng Maint	As neg by the ACO
0002	COMBS Operation	1,164,408.00 213.94 per FH
0003	Maintenance SE	13,100.00
0004	Maint Support Tech	125,000.00
0005	Bench Stock	28,200.00
0006	Data	Not separately priced
0007	Over and Above	As neg by the ACO
0008	Over and Above Fair Wear and Tear	As neg by the ACO
0009	Services Bulletin/Service Change Kits	By mod to basic contract

(a) For three aircraft.

TABLE 4-3
C-12A CONTRACT SUMMARY (1)

CLIN	Line Item	Base Year 1980 Dollars	1983 Dollars (a)
0001	Supplies & Services (29 a/c, 12099 FH)	4,600,000.00	5,905,006.40
0002	Supplies & Services for Additional FH	59.01 per FH	75.75 per FH
0003	Custom Charges on Parts Importation	1,000.00 obligated	1,283.70
0004	Over and Above	290,000.00 obligated	372,272.14
0005	Services Necessary for Damage by Crash/Collision	neg. as required	
0006	A/C Modifications	50,000.00 obligated	64,184.85
0007	Services for Reassignment of a/c	200,000.00 obligated	256,739.00
0008	Technicians TDY	20,000.00	25,673.94
0009	Material Applicable to Over and Above Work	10,000.00 obligated	12,836.97
0010	Data	not separately priced	

(a) Inflation rate is .779 (from AFR 173-13, 1 Feb 1983) 3400 O&M raw indice.

TABLE 4-4
T-43 CONTRACT SUMMARY (4) (a)

CLIN	Line Item	From Renewal Period 5 1983 Dollars (pp II-8)
0001	PDM	to be negotiated
0002	Eng Maint	to be negotiated
0003	COMBS Operation and Parts Exchange	1,602,809.00 216.27
0004	Peculiar SE Maint	43,308.00
0005	Field Services Personnel	229,796.00
0006	Bench Stock	76,709.00
0007	Over and Above	neg. as required
0008	Over and Above Fair Wear and Tear	neg. as required
0009	Tech Data	398,857.00
0010	Service Bulletin Mod.	neg. as required

(a) For nineteen aircraft.

TABLE 4-5
KC-10 CONTRACT SUMMARY (2)

CLIN	Line Item	Base Year 1976 \$	Recurring Options in 1983 \$ (a)
0001	Pre-operational planning	731,703	
0002	Data	326,131	
0003	Over and Above	negotiated as required	
0004	Returnable Investment Material (Option 1)	55,687,778 (NTE)	
0005	Site Activation (Option 2)	876,271	
0006	^(b) Maint. and Replenishment Material (Option 3)	403.26 (at 1.5 UTE) per FH	713.73 per FH
0007	^(c) Site Operation and Maintenance (Option 4)	10,950.74 per mo. per a/c	19,381.84 per mo. per a/c
0008	Data (not separately priced, included in 0004-0007)		
0009	Retrofit Kit Installation	542,283	
0010	Delivered Retrofit Kits	169,837	

(a) Inflation rate is .565 (AFR 173-13, 1 Feb 1983) 3400 O&M raw indice.

(b) The projected normal long-term UTE rate for the KC-10 is 1.5 FH/ac/day. The \$/FH comes from Section J--Option 3, FH matrix, p. 27.

(c) Per Section J--Option 4, p. 30. Price per month in base year 1976 dollars:

# of a/c	<u>1-4</u>	<u>5-9</u>	<u>10-16</u>
MOB #1	\$142,205	\$152,584	\$167,819
MOB #2	64,493	71,893	82,593
MOB #3	63,793	71,193	81,893
		<u>\$295,670</u>	

$\$295,670 \div 3 = 98,557$; $98,557 \div 9 = \$10,950.74$ per mo per a/c.

TABLE 4-6

UV-18B CONTRACT SUMMARY (6)

CLIN	Line Item	Base Year 1983 Dollars
0001	Maint Services & Supplies (2 a/c; 1650 FH)	26,025 per mo.
0002	Overhaul/Remanufacture of Engines	58,359 each
0003	Labor for Crash/Foreign Object Damage Over and Above	11.51 per hour
0004	Material to Support 0003	6,000 est.

TABLE 4-7

T-41 CLS CONTRACT SUMMARY (in 1983 dollars) (7)

CLIN	Line Item	Qty FH	\$ per FH	\$ per FH (a) - POL	% of Tot FH
0001	AF Academy Cadet Flying Trng	14,920	19.48725	5.377	.78
0002	Pilot Instructor Training	1,265	19.48725	5.377	.06
0003	Proficiency, Stan/Eval, & Miscellaneous Flying	1,500	19.48725	5.377	.08
0004	Cross Country Flying	600	4.607	4.607	.03
0005	Search and Rescue Training	110	19.48725	5.377	.01
0006	Operations & Maint	(charge is 34,695.00 per mo on \$1,285 per a/c per mo)			
0007	Functional Check Flights	120	19.48725	5.377	.01
0008	Basic Cadet Training Flights	560	19.48725	5.377	.03

(a) Per section H-22

gasoline \$1.35 per gal	10.2 gal = 1 FH	Price per FH
oil \$4.20 per gal	.08 gal = 1 FH	13.77
		.34
		<u>14.11</u>

TABLE 4-8

C-20A CONTRACT SUMMARY (17)

Line Item	1985 Dollars ^(a)	+10 % ^(b)	1983 Dollars ^(c)
Contractor Field Support	142,397	170,876.40	141,336.97
Intermediate and Depot Maintenance	440,368	484,404.80	400,665.67
Logistics Data	152,834	168,117.40	139,054.92
Support Equipment Maintenance	49,508	54,458.80	45,044.50
Parts Usage	488.22 per FH	537.04 per FH	444.20
COMBS	1,658,435		

(a) The 1985 CLS costs are for three aircraft in the leased configuration.

(b) After discussion with the C-20A cost analyst, an additional 10% was added to account for the change to production configuration.

(c) Inflation rate is 1.209 (AFR 173-13, 1 Feb 1983).

Research Question 4

4. *What line items are common to all CLS contracts?*

Table 4-9 presents a summary of all contract line items. Note that no single line item is common to all eight contracts. Several line items (COMBS operation, over and above) are common to six contracts. Equivalent CLS efforts must therefore be compared at the aircraft level by combining various line items as will be done in Chapter V.

TABLE 4-9

CONTRACT LINE ITEM SUMMARY

Line Item	C-9	T-43	E-4	C-12A	KC-10	C-20A	UV-18B	T-41
PDM	x	x						
Eng Maint	x	x					x	
COMBS Operation	x	x	x		x	x		x
Maint of SE	x	x				x		
Maint Support Tech	x	x	x			x		
Bench Stock	x	x	x					
Data	x	x	x	x	x	x		
Over and Above	x	x	x	x	x		x	
Over and Above Fair Wear and Tear	x	x		x				
Service Bulletin/Service Change Kits	x	x						
Repair &/or Replen of Spare Parts			x					
Transp of Spare Parts			x					
Additional Spares			x					
Spare Parts Maint			x					

TABLE 4-9--Continued

Line Item	C-9	T-43	E-4	C-12A	KC-10	C-20A	UV-18B	T-41
Emergency Repair			x					
Parts Usage						x		
Supplies & Services (29 a/c, 12099 FH)				x				
Supplies & Services for more FH				x				
Customs Charges				x				
A/C Modifications				x				
Services for Reassignment of A/C				x				
Technicians TDY				x				
Material for Over and Above				x			x	
Pre-operational Planning					x			
Investment Material					x			
Site Activation					x			
Maintenance and Replen Material					x			
Retrofit Kit Installation					x			
Delivered Retrofit Kits					x			

TABLE 4-9--Continued

Line Item	C-9	T-43	E-4	C-12A	KC-10	C-20A	UV-18B	T-41
Maint Services (2 A/C, 1650 FH)							x	
AF Academy Cadet Flying Training								x
Pilot Instructor Training								x
Proficiency, Stan/Eval & Misc Flying								x
Cross Country Flying								x
Search and Rescue Training								x
Function Check Flights								x
Basic Cadet Training Flights								x

CHAPTER V

RESEARCH QUESTION 5 ANSWERED

Overview

In this chapter research question 5 is restated, the possible independent variables are defined, the data base presented, and the direction of a relationship to the dependent variable proposed. Given the resulting data base a model is postulated and the dependent variable explained. Results of the regression follow with net scatter diagrams and any further models.

Research Question 5

5. *Would parametric techniques be useful in CLS estimating; i.e., is there a cost relationship for common line items between current CLS contracts?*

Independent Variables

Aircraft Empty Weight

Aircraft empty weight is defined as the weight of the structure, propulsion system, equipment, etc., in configuration defined by the mission. Note this does not include fuel or cargo. Table 5-1 summarizes aircraft empty weights.

TABLE 5-1

AIRCRAFT EMPTY WEIGHT

a/c empty weight (in lbs)	E-4	C-9A	C-12A	T-43	KC-10	UV-18B	T-41C	C-20A
	307,265	61,790	7,746	64,500	240,000	7,433	1,455	40,850 (a)
References:	(21)	(21)	(10)	(34)	(26)	(31)	(20)	(19)

(a) Predicted weight.

As empty weight increases it is logical to assume aircraft size and complexity increase. The heavier the aircraft the larger or more powerful the engines must be, or the number of engines must increase. Both conditions suggest an increased support requirement, thus an increase in CLS cost (the dependent variable) is hypothesized as aircraft empty weight increases.

Gross Maximum Takeoff Weight

Gross maximum takeoff weight is the total vehicle weight fully loaded with crew, fuel, payload, etc., to perform the mission from engine start to engine stop. Table 5-2 summarizes gross maximum takeoff weights (35).

The same rationale used to hypothesize the increase of CLS cost as the aircraft empty weight increases applies to gross maximum takeoff weight. While the same relationship is predicted, it should be less exact since aircraft empty weight is actually measured while the gross maximum takeoff weight is calculated, based on predicted mission

TABLE 5-2

GROSS MAXIMUM TAKEOFF WEIGHT

gross max T.O. weight (in lbs)	E-4	C-9A	C-12A	T-43	KC-10	UV-18B	T-41C	C-20A
	775,000	108,000	12,342	115,500	590,000	12,500	2,500	69,700
References:	(21)	(21)	(10)	(34)	(26)	(31)	(20)	(19)

payload and fuel weights. With predicted high correlation between gross maximum takeoff weight and empty weight, the former is dropped as an independent variable.

Combat Weight

Combat weight is the weight over the target for the mission presented, with fuel and oil, but without bombs, missiles, mines, cargo, or dropable tanks unless otherwise noted. Table 5-3 summarizes combat weights (35).

TABLE 5-3

COMBAT WEIGHT

combat weight (in lbs)	E-4	C-9A	C-12A	T-43	KC-10	UV-18B	T-41C	C-20A
	600,000	82,481	(a)	106,000	590,000	(a)	(a)	(a)
References:	(21)	(21)		(34)	(26)			

(a) These aircraft do not have combat missions and therefore no combat weights are available.

Since a combat weight could not be obtained for each aircraft, it will be dropped as an independent variable.

Maximum Thrust per Aircraft

Maximum thrust per aircraft equals maximum thrust per engine multiplied by the number of engines the aircraft has. Maximum thrust per engine is defined as maximum engine power output, a condition of operation which has an incremental duration time of less than thirty minutes (used for augmented and non-augmented engines) (35).

Thrust is an object's forward force measured in pounds. A jet engine's power is normally measured in thrust, but a reciprocating or turboprop engine cannot have a thrust measurement because thrust is measured in a static or fixed position on the ground. The measurement for a reciprocating or turboprop engine is in shaft horsepower or pounds of torque on the shaft. Since thrust is a measure of forward force a conversion formula is available. An efficiency factor is also used to make equivalent figures. Calculations on the C-12A, UV-18B, and T-41C follow (9).

$$\begin{array}{l} \text{Max thrust} \\ \text{per a/c in lbs} \end{array} = \text{thrust} \times \text{propeller efficiency } (.85) \quad (44)$$

$$\text{thrust} = \frac{\text{horsepower} \times 550 \text{ (ft lb/sec)}}{\text{velocity (feet/sec)}} \quad (9)$$

C-12A.

$$\text{given a/c horse power} = 1500 \quad (10; 44)$$

a/c max speed is 270 knots

$$= \frac{270 \times 6072}{60 \times 60} = \text{feet per second}$$

$$\text{Max thrust per a/c} = \frac{1500 \text{ hp} \times 550 \frac{\text{ft lbs/sec}}{\text{hp}} \times .85}{270 \frac{\text{nm}}{\text{hr}} \times 6072 \frac{\text{feet}}{\text{nm}} \times \frac{1 \text{ hr}}{3600 \text{ sec}}} \quad (44)$$

$$= \frac{(1500)(550)(.85) \frac{\text{ft lbs}}{\text{sec}}}{\frac{(270)(6072)}{3600} \frac{\text{ft}}{\text{sec}}}$$

$$= \frac{(1500)(550)(.85)}{\frac{(270)(6072)}{3600}} \text{ lbs}$$

Max thrust
of C-12A = 1540 lbs.
a/c

UV-18B.

652 hp per engine x 2 engines = 1304 hp per a/c (31)

210 mph max speed at 10,000 feet = 182 knots (31)

$$\frac{182 \text{ knots} \times 6072}{60 \times 60} = 307.217 \approx 307 \text{ feet per second}$$

$$1304 \text{ hp} = \frac{\text{thrust} \times 307}{550}$$

$$\frac{1304 \times 550}{307} = \text{thrust } 2336.1564 \approx 2336$$

2336 x .85 (propeller efficiency)

= 1986 lbs. maximum thrust per aircraft

T-41C.

145 hp per engine with one engine per a/c (32)

$$\frac{120 \text{ knots} \times 6072}{60 \times 60} = 202.4 \approx 202 \text{ feet per sec} \quad (32)$$

$$145 \text{ hp} = \frac{\text{thrust} \times 202}{550}$$

$$\frac{145 \times 550}{220} = 394.8 \approx 395 \text{ thrust in lbs.}$$

$$395 \text{ thrust} \times .85 \text{ (propeller efficiency)}$$

$$= 335.75 \text{ max thrust per aircraft}$$

As maximum thrust per aircraft increases, CLS costs are expected to increase due to the implication of large (heavier) more complicated aircraft and engines. Table 5-4 summarizes maximum thrust per aircraft.

TABLE 5-4
MAXIMUM THRUST PER AIRCRAFT

	E-4	C-9A	C-12A	T-43	KC-10	UV-18B	T-41C	C-20A
max thrust per engine	51,800	14,500	770	14,500	52,500	993	336	11,400
# of engines	4	2	2	2	3	2	1	2
max thrust per a/c (in lbs)	207,200	29,000	1,540	29,000	157,500	1,986	336	22,800
References:	(21)	(21)	(10)	(34)	(26)			(19)

Intermediate Thrust per Aircraft

Intermediate thrust per aircraft equals intermediate thrust per engine multiplied by the number of engines on one aircraft. Intermediate thrust per engine is the

maximum power output for thirty minutes. Table 5-5 summarizes intermediate thrust per aircraft (35).

TABLE 5-5
INTERMEDIATE THRUST PER AIRCRAFT

inter- mediate thrust per engine	E-4	C-9A	C-12A	T-43	KC-10	UV-18B	T-41C	C-20A
	43,225	12,600	-	12,520	46,300	-	-	-
# of engines	4	2	2	2	3	2	1	2
inter- mediate thrust per a/c (in lbs)	172,900	25,200	-	25,040	139,900	-	-	-
References:	(21)	(21)	(10)	(34)	(26)	(31)	(24)	(19)

Again, the hypothesis is that as thrust increases, CLS costs will increase due to the increase in aircraft size. Four of the aircraft do not have this data available, thus intermediate thrust per aircraft will be dropped as an independent variable.

Maximum Continuous Thrust per Aircraft

Maximum continuous, or sometimes called normal thrust per aircraft, equals maximum continuous thrust per engine multiplied by the number of engines on the aircraft. Maximum continuous thrust per engine is the maximum engine

power output which may be used continuously with no time limits imposed (35).

T-41C.

109 intermediate hp per engine with one engine
per aircraft or 75% of 145 hp (24)

average cruise speed is 130 mph (24)

$$\frac{130 \times 5280 \text{ (ft in a mile)}}{60 \times 60} = 190.66 \approx 191 \text{ ft per sec}$$

$$109 \text{ hp} = \frac{\text{thrust} \times 191}{550}$$

$$\frac{109 \times 550}{191} = 313.87 \approx 314 \text{ thrust}$$

$$\begin{aligned} 314 \text{ thrust} \times .85 (\text{efficiency}) \\ = 266.9 \text{ max continuous thrust per aircraft} \end{aligned} \quad (45)$$

Data is not available for the C-12A or UV-18B, thus maximum continuous thrust per aircraft will not be used as an independent variable. As with the other thrust variables, it was expected that as maximum continuous thrust per aircraft increased, CLS costs would also increase. See Table 5-6 for summary data.

Nautical Miles Flown
per Pound of Fuel

The ratio of nautical miles (nm) flown to one pound of fuel burned is measured with an average payload at maximum cruise speed. This variable provides a comparison on fuel consumption between aircraft (36).

TABLE 5-6

MAXIMUM CONTINUOUS THRUST PER AIRCRAFT

	E-4	C-9A	C-12A	T-43	KC-10	UV-18B	T-41C	C-20A
max continuous thrust per engine	38,684	11,400	-	12,000	10,800	-	267	10,940
# of engines	4	2	2	2	3	2	1	2
max continuous thrust per a/c (in lbs)	154,736	22,800	-	24,000	32,400	-	267	21,880
References:	(21)	(21)	(10)	(34)	(26)	(31)	(24)	(19)

E-4 (36; 40:293-295).

total fuel capacity is 46,604 U.S. gallons

46,604 x 6.5 lbs per gallon

= 302,926 lbs fuel capacity

6800 range nm ÷ 302,926 = .022 nm per lb
at 30,000 feet

C-9A (41:408).

total fuel capacity is 4,259 U.S. gallons

4,259 x 6.5 lbs per gallon

= 27,683.5 lbs fuel capacity

1670 range nm ÷ 27,683.5 = .060 nm per lb
at 30,000 feet

C-12A (40:276-277).

total fuel capacity is 544 U.S. gallons

544 x 6.5 lbs per gallon
= 3536 lbs fuel capacity

1737 range nm ÷ 3536 = .491 nm per lb
at 25,000 feet

T-43 (39:305-307).

total fuel capacity is 4137 U.S. gallons

4137 x 6.5 lbs per gallon
= 26,890 lbs fuel capacity

2300 range nm ÷ 26890 = .086 nm per lb
at 33,000 feet

KC-10 (41:412-413).

total fuel capacity is 34,958 U.S. gallons

34,958 x 6.5 lbs per gallon
= 227,227 lbs fuel capacity

9993 range nm ÷ 227,227
= .044 nm per lb

UV-18B (39:24-25).

total fuel capacity is 318 imperial gallons

318 ÷ .8327 = 382 U.S. gallons

382 x 5.9 lbs per gallon 80 octane gasoline
= 2253.8 lbs fuel capacity;

700 range nm ÷ 2253.8 = .311 nm per lb
at 10,000 feet

T-41C (40:308-309).

total fuel capacity is 49 U.S. gallons

49 x 5.9 lbs per gallon 80 octane gasoline
= 289.1 lbs fuel capacity;

440 range nm ÷ 289.1 = 1 = 1.522 nm per lb
at 6,000 feet

It is expected that as nautical miles flown per pound of fuel increases, CLS costs will decrease. This is expected due to the expected increase in fuel consumption for heavier aircraft. Table 5-7 summarizes nautical miles flown per pound of fuel.

TABLE 5-7

NAUTICAL MILES FLOWN PER POUND OF FUEL

nm per lb of fuel	E-4	C-9A	C-12A	T-43	KC-10	UV-18B	T-41C	C-20A
	.022	.060	.491	.086	.044	.311	1.522	.161

References:

(11)

Maximum Speed

Maximum speed is the highest speed obtainable in steady state, 1 g, level flight conditions. Table 5-8 summarizes maximum speed (35).

Since the highest speed obtainable is a theoretical number based on design characteristics, maximum speed figures are always calculated. It is expected that as

TABLE 5-8
MAXIMUM SPEED

max speed in knots	E-4	C-4A	C-12A	T-43	KC-10	UV-18B	T-41C	C-20A
	536	505	270	505 (a)	475 (b)	177 (c)	120 (d)	-
References:	(21)	(21)	(10)	(34)	(26)	(31)	(24)	(19)

(a) .825 mach at 20,000 feet

(b) .827 mach at 42,000 feet

(c) $204 \text{ mph} \div 1.151 = 177 \text{ knots}$

(d) $138 \text{ mph} \div 1.151 = 120 \text{ knots}$

maximum speed increases CLS cost will also increase due to increased aircraft capacity (i.e., thrust to speed relationship).

Average Cruise Speed

Average cruise speed is defined as the speed used for normal mission cruise conditions. Table 5-9 summarizes average cruise speed (35).

TABLE 5-9
AVERAGE CRUISE SPEED

average cruise speed in knots	E-4	C-9A	C-12A	T-43	KC-10	UV-18B	T-41C	C-20A
	450	470	222	440 (a)	460 (b)	139 (c)	113 (d)	501
References:	(21)	(21)	(10)	(34)	(26)	(31)	(24)	(19)

(a) .75 mach at 20,000 feet

(b) .825 mach at 42,000 feet

(c) $160 \text{ mph} \div 1.151 = 139 \text{ knots}$

(d) $130 \text{ mph} \div 1.151 = 113 \text{ knots}$

CLS costs are expected to increase as average cruise speed increases due to assumed increased thrust capacity. Since maximum speed is usually a calculated number, average cruise speed is the preferred independent variable. The two variables should be highly correlated so only average cruise speed will be used.

Aircraft Unit Flyaway Cost

Aircraft unit flyaway cost includes all production recurring and non-recurring cost categories, but does not include any research, test, and evaluation expenditures (35).

To obtain unit flyaway costs ASD cost library reports were consulted to obtain aircraft production costs and lot sizes. Since aircraft unit costs change as a function of lot size and year dollars, all costs were inflated or deflated to 1983 dollars. The AFSC CAIG generic inflation indices for aircraft are used to normalize these prior year actuals into 1983 constant dollars.

Historically, aircraft have a learning curve associated with a production run. That is, as more aircraft are produced the cost to produce an aircraft decreases, due to a learning effect. The rate of this decrease is called a learning curve. To determine if a learning curve was present for the aircraft in question, a plot was made of each lot midpoint against the lot average cost.

Inspection of these graphs shows if a typical learning curve is operating. The data for each aircraft is presented in Tables 5-10 through 5-16 followed by the graph and calculations used to determine aircraft unit flyaway cost.

E-4. Since only four E-4s were bought in two lots, as shown in Table 5-10, enough information is not available to determine if a learning curve did exist. To determine aircraft unit flyaway cost the total production cost was averaged over all four units.

$$165.11 + 71.39 = 236.50$$

$$236 \div 4 = 59.125 \text{ aircraft unit flyaway cost}$$

in constant 1983 dollars (in millions)

TABLE 5-10

E-4 UNIT COST SUPPORTING DATA (15)
(dollars in millions)

A/C Qty	Lot Cost	Year Dollars	*Indice to Inflate to 1979 \$	Lot Cost	1983 \$ ^(a) Lot Cost
2	69.0	1973	.593	116.36	165.11
2	32.3	1974	.642	50.31	71.39

(a) 1.419 used to inflate from 1979 to 1983 dollars.

* From reference 18.

C-9A. In Table 5-11 costs do not consistently decrease as more aircraft are bought. Inspection of the lot size shows a wide variability from one to six aircraft with three small lots being bought four years after the

TABLE 5-11

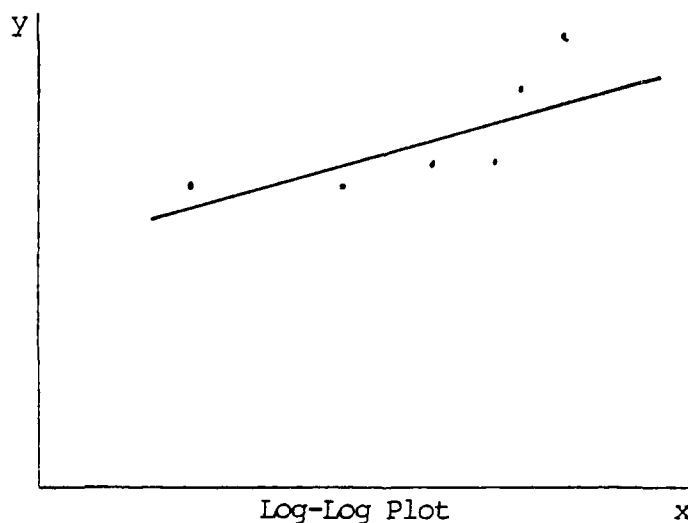
C-9A UNIT COST SUPPORTING DATA (14:2-46)
(dollars in millions)

A/C Qty	Lot Cost	Year Dollars	*Indice to Inflate to 1979 \$	1979 \$ Lot Cost	*1983 \$ ^(a) Lot Cost
5	23.1	1972	.557	41.47	58.85
3	15.6	1973	.593	26.31	37.33
6	44.0	1975	.730	60.27	85.53
1	12.8	1979	1.0	12.8	18.16
2	36.5	1981	1.251	29.08	41.27
2	54.0	1984	1.542	34.74	49.30

Lot Qty	Cum Units	Midpoint x	y = $\frac{\text{Lot Cost}}{\text{Lot Size}}$
5	5	2.5	11.77
3	8	6.5	12.44
6	14	11	14.25
1	15	14.5	14.5
2	17	16	20.6
2	19	18	24.65

(a) 1.419 used to inflate from 1979 to 1983 dollars.

* From reference 18.



majority of the aircraft were procured. Looking at the first three lots alone, costs still do not consistently decrease as expected with a learning curve. An average of the first three lots average aircraft cost results in an aircraft unit flyaway cost representative of the majority of the C-9 buy.

$$\begin{aligned} & (11.77 + 12.44 + 14.25) \div 3 \\ & = 12.82 \text{ aircraft unit flyaway cost in} \\ & \quad \text{constant 1983 dollars (in millions)} \end{aligned}$$

C-12A. Again, a learning curve is not apparent in Table 5-12. Aircraft unit flyaway cost is developed by averaging the four average aircraft cost per lot.

$$\begin{aligned} & (1.44 + 1.29 + 1.35 + 1.32) \div 4 \\ & = 1.35 \text{ aircraft unit flyaway cost in} \\ & \quad \text{constant 1983 dollars (in millions)} \end{aligned}$$

T-43. The graph in Table 5-13 shows evidence of a learning curve. A regression analysis was run using the natural log of (lot cost/lot size) as the dependent variable and the natural log of the midpoint as the independent variable. The results are presented in Figure 5-1.

The model output $Y = 2.99384 + (-.15812)X$ put in learning curve form is $Y_x = 19.96219X^{(-.15812)}$ with a learning curve slope of $\hat{S} = 2^b = .896 \approx .90$. Normalized to the 25th unit is 11.999 in constant 1983 dollars (in millions). The 25th unit was used since most USAF aircraft supported by CLS have a small fleet size.

TABLE 5-12

C-12 UNIT COST SUPPORTING DATA (14:2-50)
(dollars in millions)

A/C Qty	Lot Cost	Year Dollars	*Indice to Inflate to 1979 \$	1979 \$ Lot Cost	*1983 \$ ^(a) Lot Cost
34	20.4	1973	.593	34.40	48.82
36	25.6	1976	.783	32.69	46.39
20	16.2	1977	.851	19.04	27.01
20	17.0	1978	.913	18.62	26.42

A/C Qty	Cum Units	Midpoint x	y = $\frac{\text{Lot Cost}}{\text{Lot Size}}$
34	34	17	1.44
36	70	52	1.29
20	90	80	1.35
20	110	100	1.32

(a) 1.419 used to inflate from 1979 to 1983 dollars.

* From reference 18.

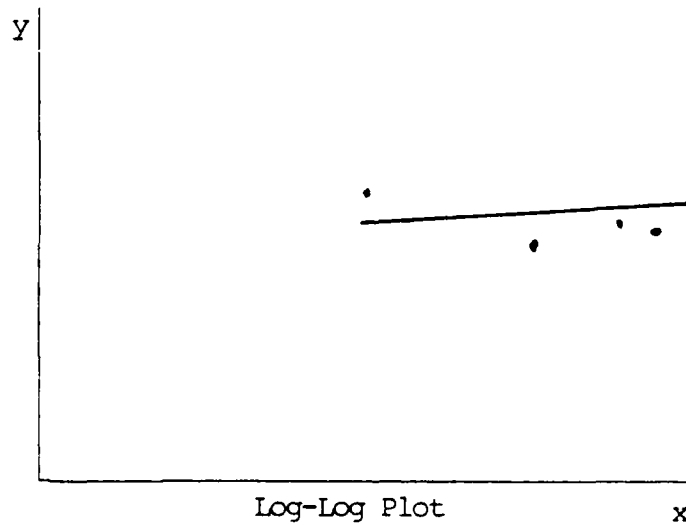


TABLE 5-13

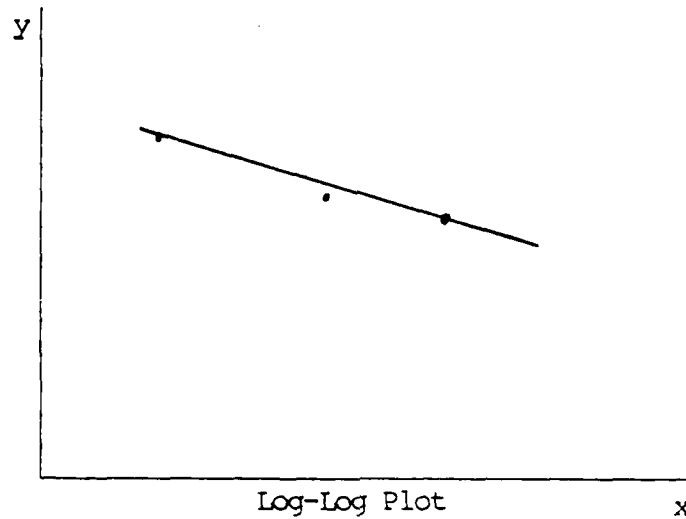
T-43 UNIT COST SUPPORTING DATA (38)
(dollars in millions)

A/C Qty	Cost per A/C	Year Dollars	*Indice to Inflate to 1979 \$	1979 \$ Lot Cost	*1983 \$ ^(a) Lot Cost
4	6.811	1971	.533	51.11	72.53
7	5.479	1972	.557	68.86	97.71
8	5.578	1973	.593	75.25	106.78

A/C Qty	Cum Units	Midpoint x	y = $\frac{\text{Lot Cost}}{\text{Lot Size}}$
4	4	2	18.13
7	11	7.5	13.96
8	19	15	13.35

(a) 1.419 used to inflate from 1979 to 1983 dollars.

* From reference 18.



MULTIPLE R	0.97806
R SQUARE	0.95661
ADJUSTED R SQUARE	0.91322
STANDARD ERROR	0.04875

ANALYSIS OF VARIANCE

	DF	SUM OF SQUARES	MEAN SQUARE
REGRESSION	1	0.05240	0.05240
RESIDUAL	1	0.00238	0.00238

F = 22.04584 SIGNIF F = 0.1336

----- VARIABLES IN THE EQUATION -----

VARIABLE	B	SE B	95% CONFIDENCE INTRVL B	BETA
L1	-0.15812	0.03368	-0.58601 0.26977	-0.97806
(CONSTANT)	2.99384	0.06700	2.14257 3.84512	

----- VARIABLES IN THE EQUATION -----

VARIABLE	CORREL	PART COR	PARTIAL	T	SIG T
L1	-0.97806	-0.97806	-0.97806	-4.695	0.1336
(CONSTANT)				44.686	0.0142

Fig. 5-1. T-43 Learning Curve SPSS Output (29)

KC-10. Graph inspection of Table 5-14 shows evidence of a learning curve effect. Since the seventh lot cost is very high without a known reason and the first lot cost is so high, aircraft unit flyaway cost is derived from an average of lots three, four, five, and seven.

$$(57.77 + 59.04 + 59.43 + 62.07) \div 4$$
$$= 59.58 \text{ aircraft unit flyaway cost in}$$
$$\text{constant 1983 dollars (in millions)}$$

UV-18B. In Table 5-15, with only one lot bought, a straight average is used.

$$3.829 \div 2 = 1.91 \text{ aircraft unit flyaway cost in}$$
$$\text{constant 1983 dollars (in millions)}$$

T-41C. T-41C data is presented in Table 5-16. A straight average is used since T-41C lot quantity was not available.

$$(.033 + .046) \div 2 = .039 \text{ aircraft unit flyaway}$$
$$\text{cost in 1983 dollars (in millions)}$$

C-20A. The unit pricing curve for the C-20A was used.

$$\text{unit price } 22.613 \text{ in 1987 dollars} \times .976 \text{ for}$$
$$9\text{th unit} = 22.07 \text{ in 1987 dollars}$$

The ninth unit was as high as the pricing curve went. Using OSD inflation rates (AFR 1973-13, 1 Feb 1983)

$$22.07 \times .827 = 18.255 \text{ aircraft unit flyaway cost}$$
$$\text{in constant 1983 dollars (in millions)}$$

TABLE 5-14

KC-10 UNIT COST SUPPORTING DATA (15)
(dollars in millions)

A/C Qty	A/C Unit Cost	Year Dollars	*Indice to Inflate to 1979 \$	1979 \$ Lot Cost	*1983 \$ ^(a) Lot Cost
2	74	1979	1.0	148	210.01
4	45.8	1980	1.125	162.8	231.08
6	52.05	1981	1.125	249.6	354.24
6	55.87	1982	1.334	251.3	356.56
8	98.76	1983	-	-	790.10
8	67.45	1984	1.542	349.9	496.56

A/C Qty	Cum Units	Midpoint x	y = $\frac{\text{Lot Cost}}{\text{Lot Size}}$
2	2	1	105.01
4	6	4	57.77
6	12	9	59.04
6	18	15	59.43
8	26	22	98.76
8	34	30	62.07

(a) 1.419 used to inflate from 1979 to 1983 dollars.

* From reference 18.

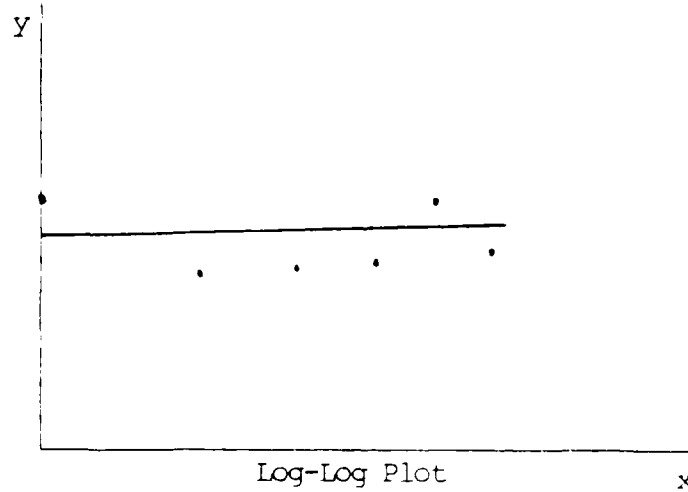


TABLE 5-15

UV-18B UNIT COST SUPPORTING DATA (14)
(dollars in millions)

A/C Qty	Lot Cost	Year Dollars	*Indices to Inflate to 1983 \$	1983 \$ Lot Cost
2	3.6	1982	1.334	3.829

*From reference 18.

TABLE 5-16

T-41C UNIT COST SUPPORTING DATA (37)
(dollars in millions)

A/C Qty	Cost per A/C	Year Dollars	*Indices to Inflate to 1979 \$	1979 \$ a/c Cost	*1983 \$ a/c Cost
(a)	.0106	1968	.452	.023	.033
	.0153	1969	.475	.032	.046

(a) Procurement of C&D models is mixed; only a Model C unit cost is given.

*From reference 18.

TABLE 5-17

AIRCRAFT UNIT FLYAWAY COST

a/c unit flyaway cost 1983 \$ (in millions)	E-4	C-9A	C-12A	T-43	KC-10	UV-18B	T-41	C-20A
	59.125	12.82	1.35	11.99	59.58	1.91	.039	18.255

As aircraft unit flyaway cost increases, aircraft size and/or complexity is assumed to increase. With increased aircraft size and complexity CLS costs are predicted to increase (Table 5-17). Tables 5-18 and 5-19 summarize the independent variables.

TABLE 5-18
SUMMARY CHART OF ALL PROPOSED INDEPENDENT VARIABLES

Independent Variable	Aircraft						
	E-4	C-9A	C-12A	T-43	KC-10	UV-18B	T-41 C-20A
Aircraft empty weight (in lbs)	307,265	61,790	7,746	64,500	240,000	7,433	1,445 40,850
Gross maximum takeoff weight (in lbs)	775,000	108,000	12,342	115,500	590,000	12,500	2,500 69,700
Combat weight (in lbs)	600,000	82,481	(a)	106,000	590,000	-	- -
Maximum thrust per aircraft (in lbs)	207,200	29,000	1,540	29,000	157,500	1,986	336 22,880
Intermediate thrust per aircraft (in lbs)	172,900	25,200	-	25,040	139,900	-	- -
Max continuous thrust per aircraft (in lbs)	154,736	22,800	-	24,000	32,400	-	267 21,880
nm flown per lb of fuel	.022	.060	.491	.086	.044	.330	1.522 .161

(a) - Indicates data is not available.

TABLE 5-18--Continued

Independent Variable	Aircraft						
	E-4	C-9A	C-12A	T-43	KC-10	UV-18B	T-41 C-20A
Maximum speed (in knots)	536	505	270	505	475	177	120 (a)
Average cruise speed (in knots)	450	470	222	440	460	139	113 501
Unit flyaway cost (in Millions) (in 1983 \$)	59.125	12.82	1.35	11.99	59.58	1.91	.039 18.255

(a) - Indicates data is not available.

TABLE 5-19

DATA BASE TO BE USED AS INDEPENDENT VARIABLES IN CERS CONSTRUCTION

Independent Variable	Aircraft						
	E-4	C-9A	C-12A	T-43	KC-10	UV-18B	T-41 C-20A
Aircraft empty weight (in lbs)	307,265	61,790	7,746	64,500	240,000	7,433	1,445 40,850
Maximum aircraft thrust (in lbs)	207,200	29,000	1,540	29,000	157,500	1,986	336 22,800
nm per lb of fuel	.022	.060	.491	.086	.044	.330	1.522 .161
Average cruise speed (in knots)	450	470	222	440	460	139	113 501
Flyaway cost in 1983 dollars (in millions)	59.125	12.82	1.35	11.99	59.58	1.91	.039 18.255

Proposed Model

$E(y) = \beta_0 + \beta_1 \text{ Empty Weight} + \beta_2 \text{ Maximum Aircraft Thrust} + \beta_3 \text{ Nautical Miles Flown per Lb of Fuel} + \beta_4 \text{ Average Cruise Speed in Knots} + \beta_5 \text{ Aircraft Unit Flyaway cost}$; where y = CLS costs.

Dependent Variable

The dependent variable (CLS cost) is developed separately for each aircraft using information from the contract summary charts of Chapter IV and are presented in Tables 5-20 through 5-26. Due to the nonuniformity of CLS line items, levels below aircraft total cost were not used. Table 5-27 summarizes the dependent variable for all seven aircraft. These costs are constructed for one year at comparable activity levels (the same number of aircraft and the same flying hours per aircraft per year).

Since the UV-18B contract is based on two aircraft with 1650 flying hours and the C-12A contract covers 29 aircraft with 12,099 flying hours, both aircraft cannot be included in the data base at the same time. The problem with both of these contracts is that the cost per aircraft cannot be separated from the cost per flying hour. As an example, the first regression will use the following aircraft CLS costs adjusted to two aircraft with 1650 flying hours (for comparability): E-4, C-9A, T-43, KC-10, UV-18B, T-41C, and C-20A.

TABLE 5-20
E-4 CLS COSTS (3)

Line Item	1983 \$ ^(a)		Adjusted to (2 A/C 1425 FH)
COMBS	3,280,000	÷ 2 =	1,640,000
Parts Repair	1,920,000	÷ 2 =	960,000
Field Support Personnel			655,841
Bench Stock	55,000	÷ 2 =	27,500
Maintenance of Spare Parts	20,000	÷ 2 =	10,000
Transportation	252,000	÷ 2 =	<u>126,000</u>
		TOTAL	3,309,341
			or \$3.309 million

(a) Costs for four aircraft.

TABLE 5-21
C-9A CLS COSTS (5)

C-9A PDM Costs	Year Dollar	* Indice	1983 \$ PDM Costs
202,666	1976	.565	358,700.88
217,000	1977	.604	359,271.52
230,500	1978	.651	354,070.66
416,000	1980	.779	534,017.97
436,000	1981	.872	500,000.00
480,000	1982	.952	504,201.68
		TOTAL	2,610,262.70

Average yearly PDM cost in 1983 \$ = \$435,043.79

<u>Engine Maintenance</u>	<u>1981 \$</u>	<u>1983 \$</u>
Hot Section Inspection	96,000	110,091.74
Engine O/H (1)	282,845	324,363.53
	TOTAL	434,455.27

<u>C-9A Contract</u>	<u>Adjusted for 2 A/C 1650 FH</u>
PDM	345,043.79
Eng. Maintenance	434,455.27
COMBS $1,164,408 \div 3 = 388,136 \times 2 =$ (per year per a/c)	776,272.00
FH $213.94 \times 1650 =$	353,001
Maint SE (assume negligible difference)	13,100
Maint Support Tech (no changes)	125,000
Bench Stock $28,200 \div 3 = 9,400 \times 2 =$ (per year per a/c)	18,800
	TOTAL 2,155,672.1 or 2.156 million

* From reference 45.

TABLE 5-22
T-43 CLS COSTS (4)

Line Item ^(a)			Adjusted to 2 A/C 1650 FH
	(1982 \$)	(1983 \$)	
PDM	489,000	$513,655.46 \div 2 =$	256,827.73
ENG MAIN }	1 a/c PDM/HSI		
COMBS	$(1,602,809 \div 19 = 84,358.37)$	$\times 2 =$	168,716.74
FH	$216.27 \times 1650 =$		356,845.50
SE Maint	$(43,308 \div 19 = 2,279.37)$	$\times 2 =$	4,558.74
Field Service Personnel	(no change)		229,746.00
Bench Stock	$(76,709 \div 19 = 4,037.32)$	$\times 2 =$	8,074.63
Tech Data	$(398,857 \div 19 = 20,992.47)$	$\times 2 =$	<u>41,984.95</u>
		TOTAL	1,066,804.30
			or 1.067 million

(a) Costs are for 19 aircraft.

TABLE 5-23
KC-10 CLS COSTS (17)

Line Item (1983 \$)		Adjusted for 2 A/C 1650 FH
FH	$713.73 \times 1650 =$	1,177,654.50
A/C	$(19,381.84 \times 12) \times 2 =$ per mo. a/c	<u>465,164.16</u>
	per a/c	TOTAL 1,642,818.66
		or 1.643 million

TABLE 5-24
UV-18B CLS COSTS (6)

Line Item (1983 \$)		Adjusted for 2 A/C 1650 FH
Maint Services (2 a/c 1650 FH)	$26,025 \times 12 =$ per mo mo	312,300
Eng. Overhaul (1)		<u>58,359</u>
		TOTAL 370,659
		or .371 million

TABLE 5-25

T-41 CLS COSTS (7)

Line Item	Adjusted for 2 A/C 1650 FH
1650 FH	
.03% @ \$4.607 x 49.5 =	228.05
.97% @ 5.377 x 1600.5 =	8,605.89
Operations & Maint (1,285 x 12) x 2 = per a/c per mo	30,840.00
TOTAL	39,673.94
or .040 million	

TABLE 5-26
C-20A CLS COSTS (7)

Line Item	1985 \$	+ 10%	Adjusted CLS Cost 1983 \$
Field Support	142,397	170,876.40	141,336.97
COMBS	1,658,435 (3 a/c) 1,105,623.30 (2 a/c)	1,216,185.70	1,005,943.50
Depot	440,368 (3 a/c) 293,578.67 (2 a/c)	322,936.53	267,110.45
Data	152,834	168,117.40	139,054.92
Support Equipment Maintenance	49,508 (3 a/c) 33,005.33 (2 a/c)	36,305.87	30,029.67
Parts Usage	488.22	537.04 x 1650 = 886,119.3	732,935.73
		TOTAL	2,316,411.2
		or 2.316 million	

TABLE 5-27

SUMMARY OF CLS COSTS

CLS cost	E-4	C-9A	T-43	KC-10	UV-18B	T-41	C-20A
2 a/c							
1650 FH	3.309	2.156	1.067	1.643	.371	.040	2.316

Least Squares Regression

A least squares regression was performed using all variables of the proposed model. Results are found in Table 5-28. Results show only one nonsignificant t value (for nm per lb of fuel) and the F test was significant. In addition, the coefficients for empty weight and aircraft unit flyaway cost have the opposite sign predicted. An examination of the correlation matrix shows empty weight and maximum aircraft thrust to be highly correlated (.986).

Historically, aircraft unit flyaway cost has been determined using aircraft speed and aircraft weight. Since both empty weight and average cruise speed are variables it is logical to delete aircraft unit flyaway cost as an independent variable. Having a high correlation between empty weight and maximum aircraft thrust requires that one of these variables be dropped. Since empty weight is a measured variable and some of the maximum aircraft thrust data had to be calculated, empty weight is the better variable and will remain.

TABLE 5-28

PROPOSED MODEL REGRESSION OUTPUT (29)

Array: 7 by 5		Independent Variables				
		WEIGHT [,1]	THRUST [,2]	FUEL [,3]	SPEED [,4]	FLYAWAY COST [,5]
E-4	[1,]	307.265	207.200	0.022	450	59.125
C-9A	[2,]	61.790	29.000	0.060	470	12.820
T-43	[3,]	64.500	29.000	0.086	440	11.990
KC-10	[4,]	240.000	157.500	0.044	460	59.580
UV-18B	[5,]	7.433	1.986	0.330	139	1.910
T-41C	[6,]	1.445	0.336	1.522	113	0.039
C-20A	[7,]	40.850	22.800	0.161	501	18.255

Dependent Variable

3.309 2.156 1.067 1.643 0.371 0.040 2.316
 >regress(x1,y1)

		Coef	Std Err	t Value
	Intercept	-0.1903444	0.8839951	-0.215323
WEIGHT	x2	-0.08749300	0.04054239	-2.158062
THRUST	x3	0.1538800	0.06231184	2.469516
FUEL	x4	-0.4570376	0.6173031	-0.740378
SPEED	x5	0.00880284	0.002600203	3.385442
FLYAWAY	x6	-0.09178564	0.04371553	-2.099611

Residual Standard Error = 0.4738042

Multiple R Square = 0.971797

N = 7

F Value = 6.89141 on 5, 1 df

 t_{crit} at $\alpha = .05$ is 1.943 F_{crit} at $\alpha = .05 = 6.61$

Correlation matrix of coefficients:

		Intercept	x2	x3	x4	x5
WEIGHT	x2	-0.1754865				
THRUST	x3	0.1416782	-0.9822562			
FUEL	x4	-0.8338033	0.3319072	-0.3118162		
SPEED	x5	-0.6293652	-0.5599881	0.6121953	0.3347617	
FLYAWAY	x6	0.0858302	0.3440496	-0.5093576	0.0719252	-0.547406
COST						

Second Proposed Model

$E(y) = \beta_0 + \beta_1 \text{ Empty Weight} + \beta_2 \text{ Nautical Miles per Lb of Fuel} + \beta_3 \text{ Average Cruise Speed in Knots};$
where y = CLS cost.

Dependent Variable

The dependent variable remains the same as in the last model.

Least Squares Regression

A least squares regression was performed on the second proposed model. Results are found in Table 5-29. Results show the variable coefficients with the expected signs but a nonsignificant r . The t values for all variables are not significant. Since nautical miles flown per pound of fuel has the lowest t values and empty weight is a more accurately measured variable, fuel consumption will be dropped as a variable.

As a test for aptness of model fit, net scatter diagrams for the variables are found in Figures 5-2, 5-3, and 5-4. As the figures show, linearity of each variable cannot be rejected.

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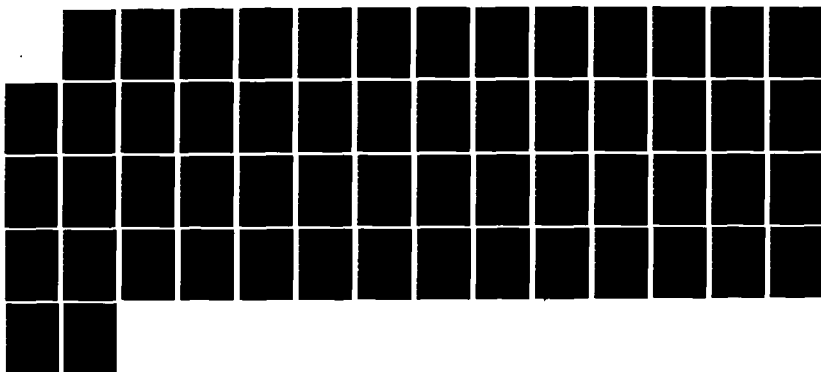
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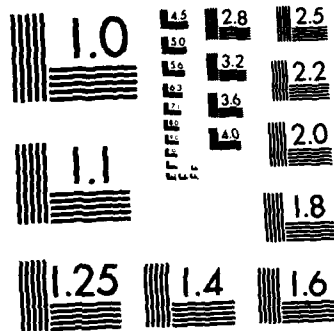
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MICROCOPY RESOLUTION TEST CHART
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TABLE 5-29

SECOND PROPOSED MODEL REGRESSION OUTPUT (29)

MULTIPLE R	0.87910
R SQUARE	0.77282
ADJUSTED R SQUARE	0.54563
STANDARD ERROR	0.77639

ANALYSIS OF VARIANCE

	DF	SUM OF SQUARES	MEAN SQUARE
REGRESSION	3	6.15143	2.05048
RESIDUAL	3	1.80833	0.60278

F = 3.40172 SIGNIF F = 0.1707

VARIABLES IN THE EQUATION

VARIABLE	B	SE B	95% CONFIDENCE INTRV B	BETA
SPEED	0.00418	0.00316	-0.00588 0.01423	0.60287
WEIGHT	0.00365	0.00311	-0.00626 0.01356	0.38148
FUEL	-0.04267	0.95565	-3.08393 2.99860	-0.02005
(CONSTANT)	-0.34088	1.40905	-4.82503 4.14327	

VARIABLES IN THE EQUATION

VARIABLE	CORREL	PART COR	PARTIAL	T	SIG T
SPEED	0.81512	0.36355	0.60646	1.321	0.2782
WEIGHT	0.70193	0.32250	0.56039	1.172	0.3258
FUEL	-0.67988	-0.01229	-0.02577	-0.045	0.9672
(CONSTANT)				-0.242	0.8244

Y	*PRED	*RESID
3.3090	2.6585	0.6505
2.1560	1.8445	0.3115
1.0670	1.7281	-0.6611
1.6430	2.4538	-0.8108
0.3710	0.2526	0.1184
0.0400	0.0713	-0.0313
2.3160	1.8933	0.4227
Y	*PRED	*RESID

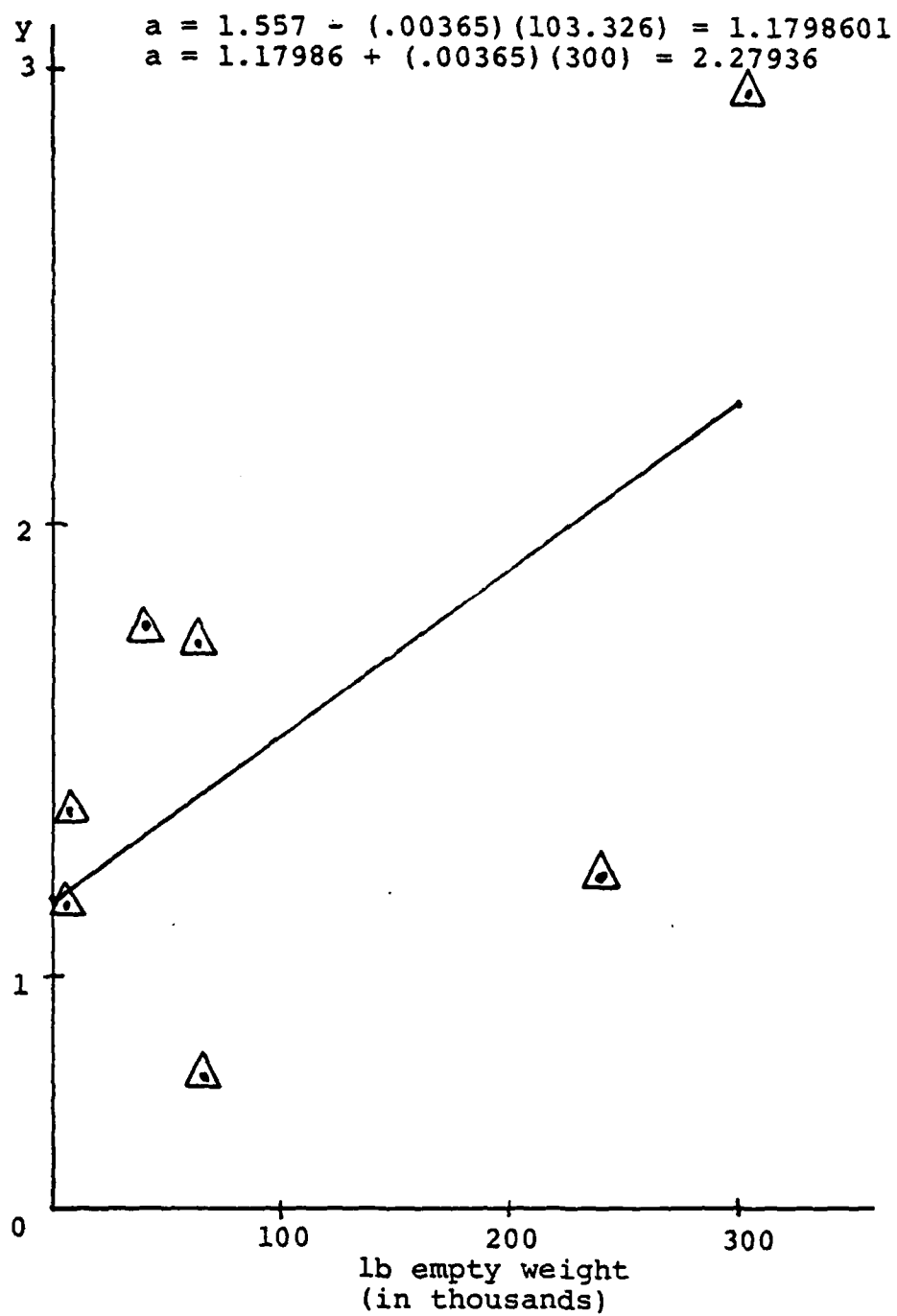


Fig. 5-2. Empty Weight Net Scatter Diagram

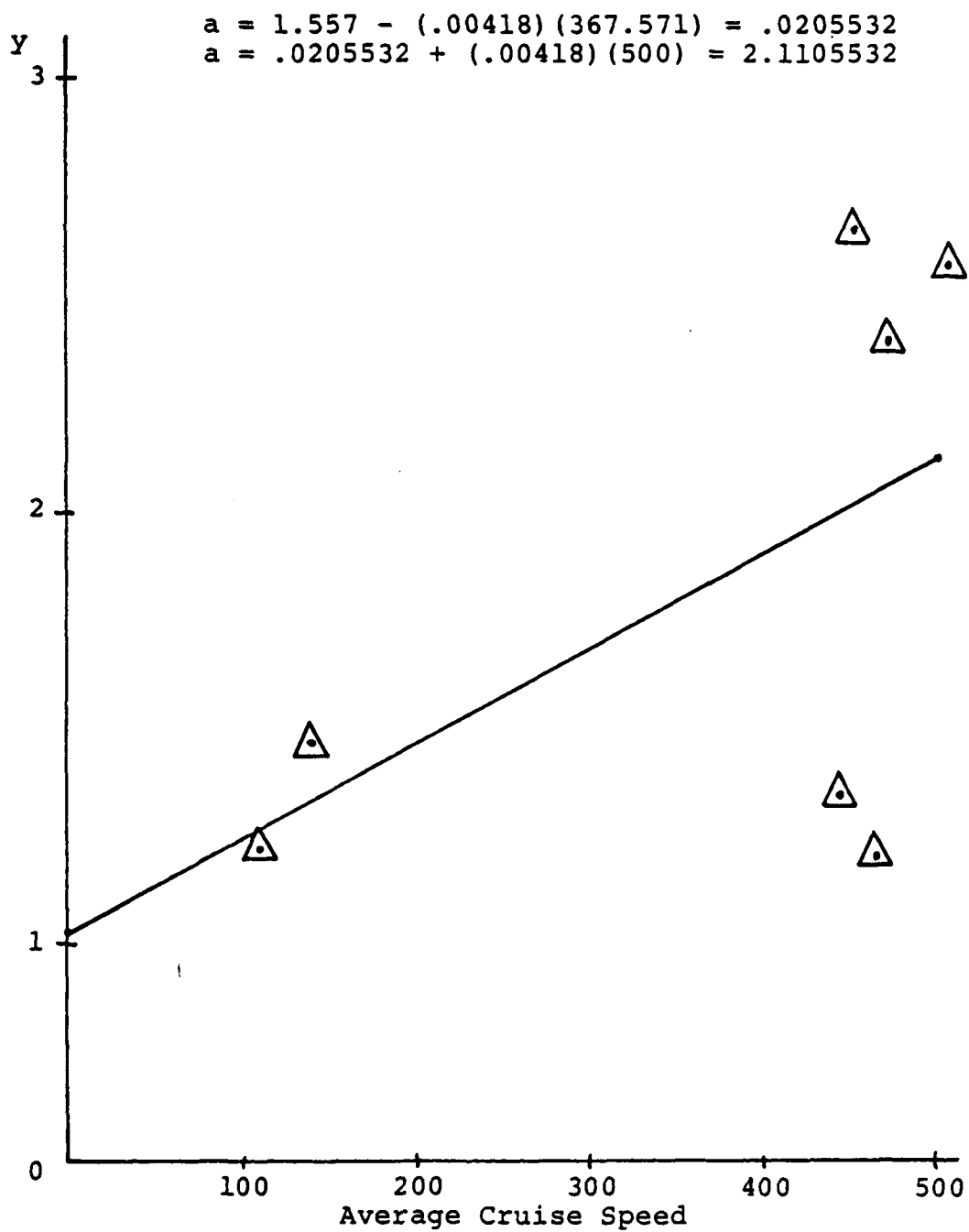


Fig. 5-3. Average Cruise Speed Net Scatter Diagram

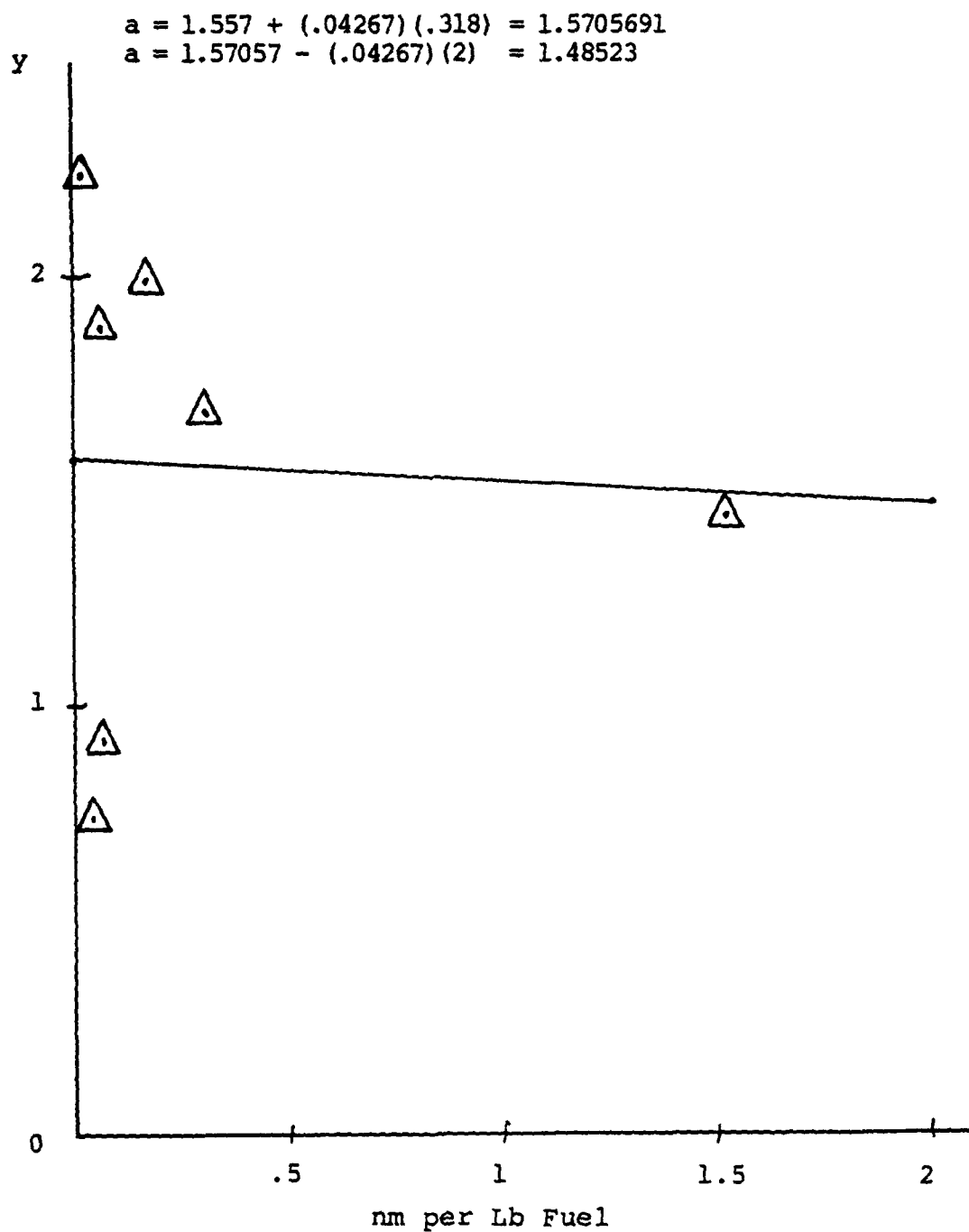


Fig. 5-4. Nautical Miles per Pound of Fuel
Net Scatter Diagram

Third Proposed Model

$E(y) = \beta_0 + \beta_1 \text{ Empty Weight} + \beta_2 \text{ Average Cruise Speed in Knots}$; where y = CLS costs.

Dependent Variable

The dependent variable remains the same as in the previous model.

Least Squares Regression

A least squares regression was performed on the third proposed model. Results are found in Table 5-30. Results of the regression show a significant F statistic, positive coefficients for average cruise speed and empty weight, and an R^2 of .77. Note that the t value for the empty weight coefficient is not significant.

This is our best model. Given a new aircraft empty weight and average cruise speed, the following equation will predict the CLS cost for one year of two aircraft flying a total of 1650 hours. The CLS cost will be in 1983 dollars, in millions. Empty weight is input in thousands of pounds and average cruise speed is input in knots per hour.

$$E(y) = - .39367 + (.00367) \text{ Empty Weight} + (.00428) \text{ Average Cruise Speed}$$

TABLE 5-30

THIRD PROPOSED MODEL REGRESSION OUTPUT (29)

MULTIPLE R	0.87901
R SQUARE	0.77267
ADJUSTED R SQUARE	0.65900
STANDARD ERROR	0.67259

ANALYSIS OF VARIANCE

	DF	SUM OF SQUARES	MEAN SQUARE
REGRESSION	2	6.15023	3.07512
RESIDUAL	4	1.80953	0.45238

F = 6.79759 SIGNIF F = 0.0517

VARIABLES IN THE EQUATION

	B	SE B	95 % CONF INTRVL B	BETA
SPEED	0.00428	0.00193	-0.00107 0.00962	0.61735
WEIGHT	0.00367	0.00266	-0.00372 0.01106	0.38387
(CONSTANT)	-0.39367	0.66412	-2.23754 1.45021	

VARIABLES IN THE EQUATION

VARIABLE	CORREL	PART COR	PARTIAL	T	SIG T
SPEED	0.81512	0.52911	0.74288	2.219	0.0907
WEIGHT	0.70193	0.32901	0.46794	1.380	0.2397
(CONSTANT)				-0.593	0.5852

Y	*PRED	*RESID
3.3090	2.6588	0.6502
2.1560	1.8429	0.3131
1.0670	1.7245	-0.6575
1.6430	2.4545	-0.8115
0.3710	0.2280	0.1430
0.0400	0.0948	-0.0548
2.3160	1.8985	0.4175
Y	*PRED	*RESID

As a test for aptness of model fit, net scatter diagrams for the two variables in the final model are found in Figures 5-5 and 5-6. As the figures show, linearity of each variable cannot be rejected.

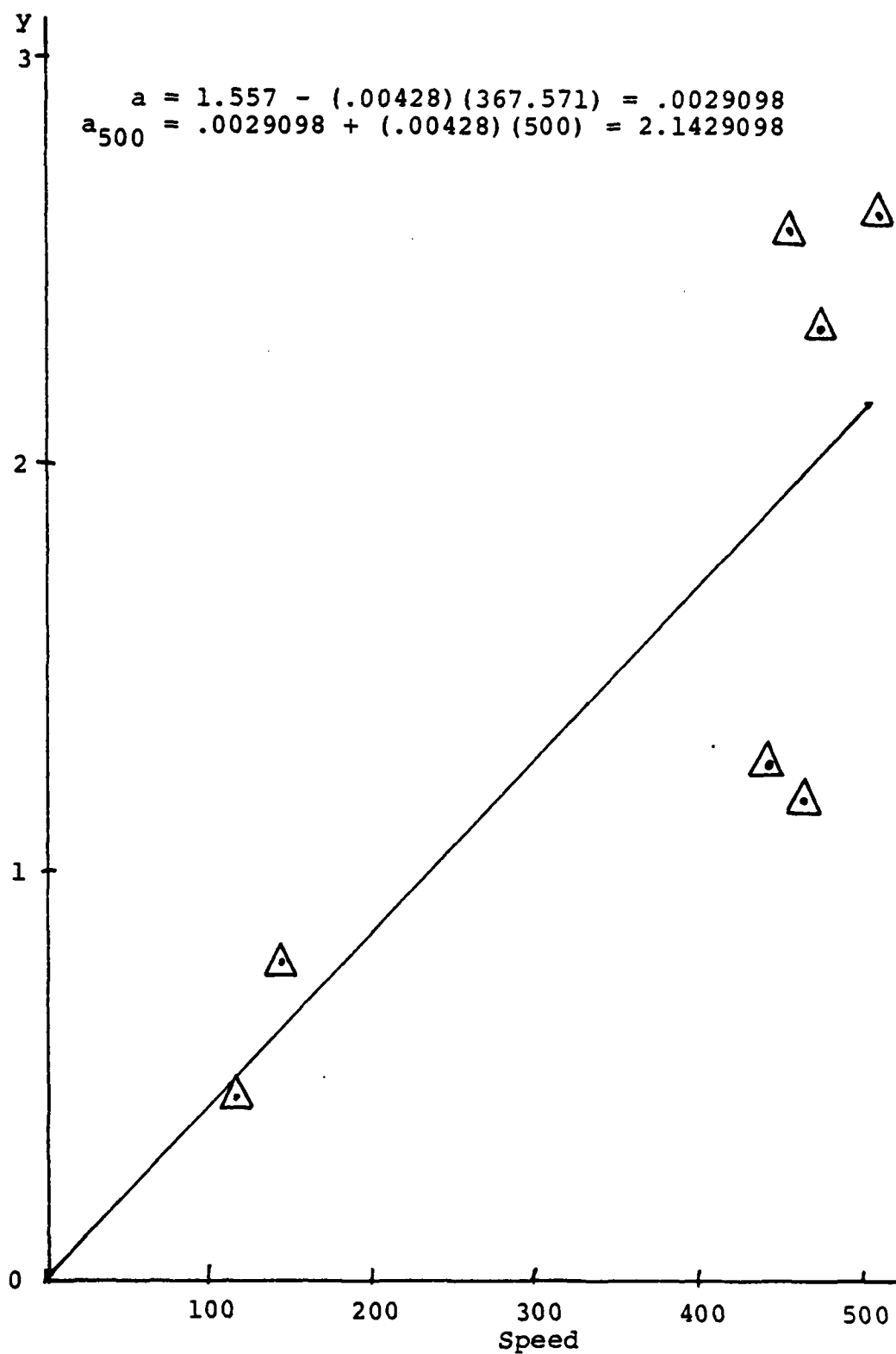


Fig. 5-5. Average Cruise Speed Net Scatter Diagram

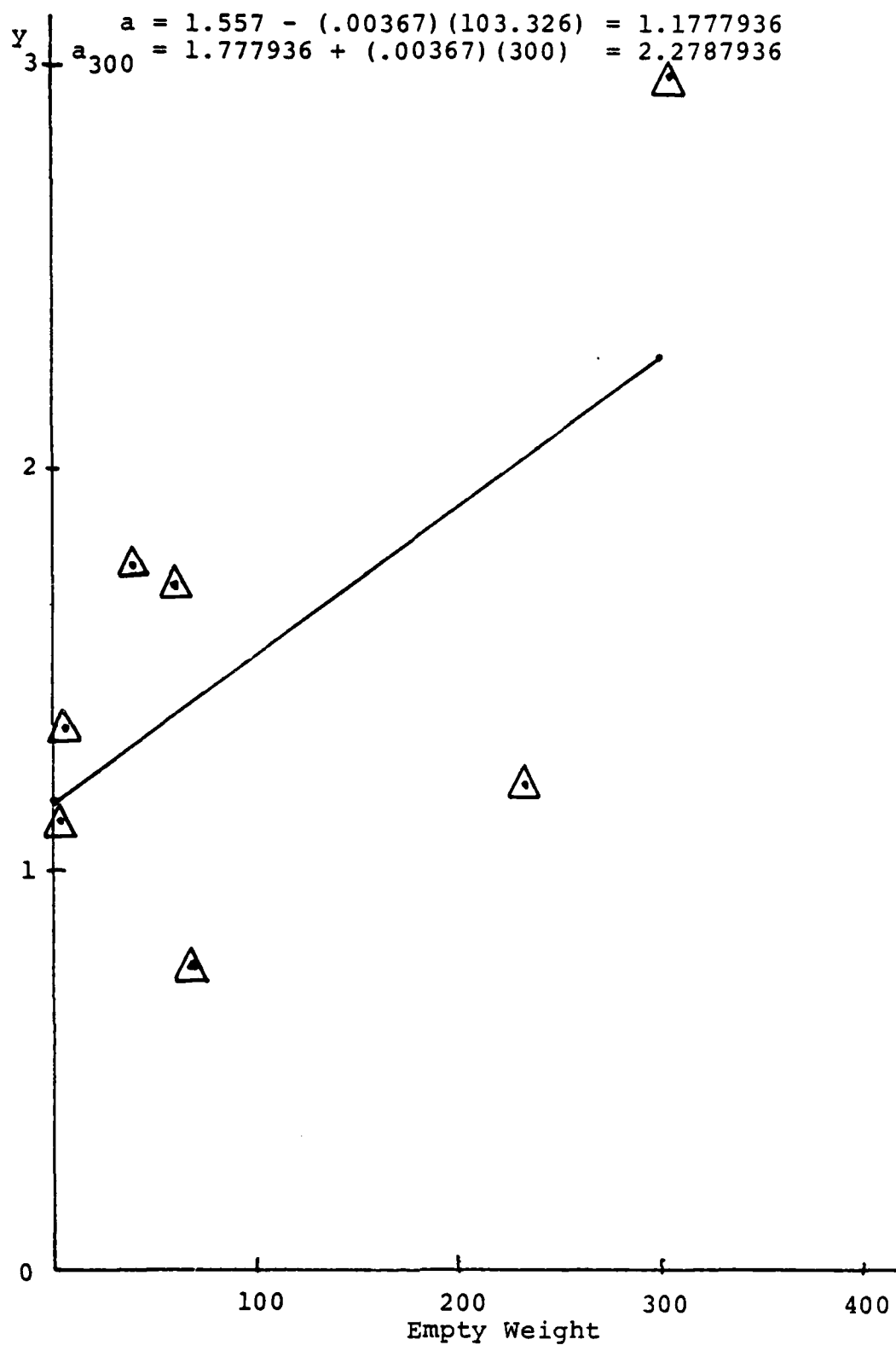


Fig. 5-6. Empty Weight Net Scatter Diagram

CHAPTER VI

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

This research has explored the use of the parametric method for CLS estimation. Comparison of the CLS contracts was presented in Chapter IV and a data base was constructed in Chapter V. The parametric procedure in Chapter V uses aircraft physical and performance characteristics to estimate CLS costs with limitations stated below. The data base also provides for alternative procedures to be used at the cost analyst's discretion.

Parametric Procedure

Any new aircraft with CLS proposed as a support concept will have an estimated aircraft fleet size and an estimated yearly flying hour program. Chapter V provides an example of using the parametric procedures. The dependent variable was constructed based on two aircraft with 1650 flying hours. A model was proposed, least squares regression performed, and a model fit analysis performed. This procedure was continued until a final model was determined. The resulting equation, given aircraft empty weight and average cruise speed, calculates CLS costs for one

year in 1983 dollars, in millions, for two aircraft flying 1650 hours.

If the proposed aircraft fleet is not a multiple of two and the proposed flying hours per aircraft per year does not equal 825, then the final model in Chapter V cannot be used. To demonstrate how the data can be used if the assumptions are not met, suppose an estimate of fifty-eight aircraft with a projected flying hour program of 417 hours per aircraft per year is desired. The dependent variable must be constructed using CLS cost data from Chapter IV on the E-4, C-9A, C-12A, KC-10, T-41, T-43, and the C-20A. The CLS costs would be adjusted to twenty-nine aircraft flying 12099 hours per year (a restriction of the C-12A data). The same procedures used in Chapter V to develop the final model would be followed. The model output (y) multiplied by two would then represent the one year's CLS cost in 1983 dollars, in millions, for fifty-eight aircraft flying 417 hours per year per aircraft. This is just one other example of how the data could be manipulated to help construct an aircraft CLS estimate parametrically.

To employ the parametric procedure, the following six steps should be followed. First, the data base found in Table 5-18 should be consulted. Any independent variable whose information is not available or able to be constructed for the proposed aircraft should be deleted. Since most

aircraft with CLS proposed are off-the-shelf, aircraft characteristic data should be available from the manufacturer or Jane's All the World's Aircraft.

Second, the independent variable for the proposed aircraft should be compared to the range of the current data base. The variables that are outside of the data base range should be considered for deletion.

Third, using the list of remaining independent variables and some logic, a model is proposed. The fourth step is to construct the dependent variable making sure that each value is comparable. Recognize that with the data base provided either the UV-18B or the C-12A must be dropped from the data base, for reasons previously explained.

The fifth step is to perform a least squares regression. Should a new CLS aircraft enter the inventory (providing a new data point), least squares regression should be redone. The construction of net scatter diagrams to test the aptness of the model is the sixth step. Measures of fit and significance are also evaluated. Steps three through six are continued until a final model is developed.

Alternate Procedure

Time constraints, lack of aircraft characteristic data, or proposed aircraft outside the data base range may necessitate an alternative approach. The cost analyst

may determine that using one of the aircraft in the data base for an analogy approach would result in a better estimate. This might be particularly true if the proposed aircraft were very similar to one of the aircraft in the data base. An example of the analogy approach is given in Chapter I with the Tanker Trainer Bomber study. The data base provided allows the timely use of this approach.

Recommendations

Three recommendations come out of this research effort. When a new aircraft CLS cost estimate is required, the parametric procedure presented in Chapter V and the Conclusions section of this chapter should be considered. With the aircraft characteristic data base now available, the parametric approach is now viable.

A second recommendation comes from the contract comparisons made in Chapter IV. CLS contracts have basically been exceptions to the more typical Air Force organic support concept and show little continuity between contracts. This is highlighted by the fact that not one contract line item is common to all eight CLS contracts. This resulted in a parametric procedure based on total CLS costs. If several line items had been common across the CLS contracts, separate CERs could have been developed for those line items. In view of the projected increase in CLS contracts (Tanker Trainer Bomber, European Distribution

System Aircraft, and the Operational Support Aircraft) having separate CERs for line items would be preferred. The only way to develop such CERs would be to have similar contract structures for all CLS contracts. The second recommendation is to impose as a minimum requirement that CLS contracts separate out per flying hour charges, per aircraft charges, and depot maintenance charges. This limited requirement would facilitate CER development.

This second recommendation is not intended to mandate a fixed contract structure. While CER construction would be greatly simplified by an exact contract line item structure (and the Navy has done this), the advantage of using CLS could be lost. As demonstrated by the diversity of the eight aircraft used in this research effort, CLS is a flexible concept. The nature of small, special-mission aircraft fleets requires flexibility. The basing concepts range from the C-12A based in ones or twos worldwide to the more typical T-43s based at Mather AFB. Thus, to mandate a completely fixed contract structure is not recommended.

The construction of the dependent variable (CLS costs) on the C-9A and the T-43 highlight the need for more cost data, the third recommendation. The PDM and engine hot section inspection costs on the T-43 and C-9A were difficult to isolate. Most of the CLS contracts do require cost data visibility. Obviously, total cost

visibility is impractical and too expensive but some level of cost data should be required. Visibility into more detailed cost data would enhance recompetition of CLS contracts as well as a government CLS cost data base to be used for CER development. Implementing the second recommendation would provide part of this cost data visibility.

Further Research Needs

With the projected increase of CLS in the DOD several aspects of CLS should be examined. Two areas needing examination are cost data collection systems for CLS and integrating CLS maintenance data collection needs with current Air Force systems. Due to the limited data requirements on the CLS contracts, what information is being input to Air Force data collection systems versus what is needed should be researched.

The question of the effectiveness of CLS needs to be addressed. A historical examination of CLS performance should be attempted using contract performance requirements and specifically compiling a report on response of the contractors during crisis situations. With some long-term CLS aircraft in the inventory an alternate approach would be to apply time series analysis to historical maintenance records where available.

In summary, the whole area and concept of CLS merits further research and closer management attention if good aircraft CLS cost estimates are to be made in the future. Information on past performance and the effectiveness of CLS should also be available if CLS is to be evaluated as an alternative support concept on new military aircraft systems.

APPENDICES

APPENDIX A
CONTRACT OVERVIEWS

E-4

The Boeing Company provides CLS for the USAF E-4s at Offutt AFB. The AF is responsible for organizational level maintenance, remove and replacement on-aircraft while intermediate and depot level maintenance is performed by the contractor. Options are available to continue logistic support out through fiscal year 1987. This contract covers support for the four E-4s. Descriptions follow of the ten major line items which make up the contract (3).

Line item 0001 has a firm fixed price for COMBS operation and maintenance at Offutt AFB. Service is provided twenty-four hours a day, 365 days per year. Parts necessary to support the E-4As at 700 flying hours per year and the E-4B at 725 flying hours per year will be stocked. All spare parts repair will be by FAA approved sources. The Air Force is responsible for parts transportation from the COMBS to the aircraft. On-board/forward operating base/deployment spares are furnished by the contractor. COMBS will support selected intermediate level engine maintenance and quick engine change spare parts. All support equipment and special test equipment will be supported by the contractor as well (3:2).

CLIN 0002 is an annual fixed price for repair and/or replenishment of spare parts. All parts removed from the aircraft are returned to the contractor for repair or

replenishment. Title to all parts while on the aircraft rests with the government. When parts are turned in to the COMBS, the ownership transfers back to the contractor (3:2).

CLIN 0003 pays for contractor field support representatives. These representatives include one communication/navigation avionics expert, one electrical system expert, and two aircraft/aircraft system experts. The representatives are to provide technical guidance in resolution of field problems, on the job training, classroom training, instruction in the aircraft, troubleshooting assistance, and other related tasks. Representatives may be required to work at locations other than the main operating base and other than normal duty hours. The line item is firm fixed price with sub-line items specifying specific annual cost associated with the different type of field service representative (3:2).

The contractor provides bench stock of high usage nonrecoverable rotation type items under CLIN 0004. Stock includes contractor furnished hardware and nonmilitary specified soft consumables. The contractor will perform periodic stock replenishment and inventory. The bench stock will be located in government facilities (3:2).

Line item 0005 covers all required data. The price of this data is included in CLIN 0001. CLIN 0006 pays all transportation charges for spare parts to support the requirements identified in CLINS 0002, 0004, 0007, 0008,

and 0009. The contractor will be reimbursed for the actual shipment costs incurred. Line item 0007 covers the cost of all E-4 unique and common spare parts added to the spares support list. Transportation charges to the COMBS or storage site is also included. CLIN 0008 allows for modification, recertification test, calibration, periodic maintenance and/or improvements to stocked spare parts. The contractor will accomplish such work as necessary to assure the integrity of the E-4 spares inventory. CLIN 0006, 0007, and 0008 are not firm fixed prices but have an estimated yearly dollar amount (3:2).

CLIN 0009 handles emergency repair and mission essential unscheduled maintenance as authorized by the principle contracting officer or his representative. Price for all work and supplies will be negotiated by the Administrative Contracting Officer (ACO). The line item has a not to exceed dollar value over which the government cannot be obligated (3:3).

Line item 00010 also covers over and above work when authorized by the ACO. Five sub-line items specify the following type of work: field team crash damage repair, unscheduled depot level maintenance, support equipment heavy maintenance, corrosion control, and modifications resulting from Service Bulletins or other work as may be authorized by the ACO. Payment procedures are the same as for CLIN 0009 (3:3).

In summary, the E-4 is contractor maintained for intermediate and depot level maintenance via a CLS contract

with Boeing. The contract has ten line items: COMBS operation, spare parts repair/replenishment, contractor field representatives, bench stock, data, parts transportation charges, additional spares, spares maintenance/modifications, emergency repair, and specific over and above authorized work. Additional line items cover the same services for fiscal year 1984 through fiscal year 1987 (3:1-5).

C-9A

The C-9A support contract with Douglas Aircraft Company has an effective date of 1 March 1980 and includes yearly options to continue support through 1984. The contract covers support of three C-9A Special Air Mission Aircraft with a utilization rate of sixty-five hours per month. The Using Command will perform removal and replacement of parts, system operational checkout, pre-flight and post-flight inspection, dash six T.O., and dash one flight manual inspections. The contractor will repair all removed parts and other off-equipment maintenance. The contract has nine major line items as discussed below (5).

Contract Line Item Number (CLIN) 0001 is subdivided into five parts. The CLIN includes all Programmed Depot Maintenance (PDM) defined as phased Federal Aviation Administration (FAA) Airworthiness D and E Inspection/Repair/Isochronal Inspection. The work must be authorized by the Principle Contracting Officer and use FAA approved procedures. Work flow time cannot exceed fifteen calendar

days. The aircraft flight testing will be done by government and contractor personnel. The Air Force will transport aircraft to and from the contractor's FAA approved facility. This PDM is scheduled every eighteen months and has a negotiated price per aircraft (CLIN 0001AA). As a modification, CLIN 0001AB covers PDM with landing gear replacement to be added by a supplemental agreement. CLIN 0001BA covers scheduled or unscheduled engine maintenance. Work to be accomplished must be requested by the Administrative Contracting Officer (ACO) and negotiated as an over and above item. CLIN 0001CA and 0001CB provide for exterior aircraft painting when authorized by the PCO. Prices on each part of CLIN 0001 must be negotiated and added by supplemental agreement. Due to the small C-9 fleet CLIN 0001 may not be exercised each year (5:1-3).

The second line item includes all work associated with the Contractor Owned and Maintained Base Supply (COMBS) operation at Andrews AFB. Both recoverable and expendable spare and repair parts are maintained. FAA approved sources shall accomplish any repair. All applicable items will be FAA certified. The contractor is responsible for all approved spare modifications and all parts in the COMBS to the aircraft. Normal COMBS operations will be five days a week with two shifts. Additional support at all other times will be on an as-needed basis. All items removed from the aircraft are to be returned to the contractor with a DD 250

title transfer. Items on the aircraft are government owned. This CLIN covers all supplies and services for base supply except the government-furnished aeronautical equipment, TACAN, and all engine maintenance. The price is a yearly basic fixed price plus a price per flying hour per aircraft per month (5:3-5).

Line item three is an annual price for the maintenance (including calibration) and repair of all C-9A peculiar support equipment. The contractor will hold title to the support equipment. CLIN 0004 allows for two maintenance support technicians to be available to the Using Command; one qualified aircraft general maintenance technician and one qualified avionics systems maintenance technician. CLIN 0005 covers bench stock of high usage nonrecoverable type items in response to maintenance requirements. The only exception is that MIL-Spec soft consumables will be furnished by the government. Line items three through five are firm fixed price, annually. The price of deliverable data (CLIN 0006) is included in these line items (not specifically priced) (5:6-7).

Over and above work, work not within the scope of line items one through six, is to be accomplished under CLIN 0007 and 0008 when and as directed by the ACO. Under CLIN 0008 the contractor shall repair and replace items damaged over and above fair wear and tear. The contractor will provide documentation to verify the work is excluded from the

rest of the contract. CLIN 0007 covers all work to be identified by the ACO and not covered by other line items. Anticipated usage includes field teams, crash damage repair, and depot level maintenance not already contemplated. Each ACO work request will be separately negotiated and added by supplemental agreement (5:7-8).

The procurement and installation of Service Bulletin/Service Change Kits are accomplished under line item 0009. These changes may be ordered by the government and will be added as a basic contract modification (5:8).

The contract provides yearly options on all line items for four additional years (out through 1984) with prices where applicable. At the conclusion of each contract year the contractor will develop a revised list of items added by the contractor during the year. This list is the new spares list. If the Air Force does not continue logistic support by this same contractor the government will purchase all items on the spares list. The contractor further specifies required delivery times and transportation requirements. The contract also provides for Air Force personnel to accompany FAA personnel to subcontractor facility visits. Payments on all active line items will be made monthly (5:9-11).

To summarize, the C-9A CLS contract with Douglas Aircraft Company, provides for all maintenance and repair except for flightline (remove and replace) duties to be performed by the using command. The contract has the

following nine contract line items: PDM, COMBS operation, support equipment maintenance, maintenance support technicians, bench stock, data, over and above work, and Service Bulletin/Service Change Kits. Yearly options allow for CLS to be continued through fiscal year 1984 (5).

C-12A

The USAF C-12A logistic support contract with Beech Aerospace Services, Inc. provides for total maintenance and material support for twenty-nine C-12A aircraft on a worldwide basis. FAA standards for maintenance and airworthiness will be maintained. The contractor provides organizational, intermediate, and depot level maintenance with an assurance of 80 percent Operational Readiness (OR) rate. The C-12As are assigned to Defense Attache Offices, Military Advisory Assistance Groups, Military Airlift Command, Alaskan Air Command, Pacific Air Forces, and USAF Europe. Worldwide beddown bases are specified but are subject to changes during the period of contractual logistics support. The contract has ten line items as described below (1).

Line item 0001 includes all supplies and services to support the twenty-nine aircraft for 12,099 flying hours. The line item has a firm fixed price for one year. Organizational, intermediate, and depot level maintenance as well as pre-flight and post-flight inspections are included. Depot maintenance will be done by major component

replacement at the beddown bases. Spares, parts, and engines will be contractor furnished. This line item includes unscheduled maintenance away from the beddown base. The contractor will maintain maintenance records and accomplish all Urgent/Immediate Action Time Compliance Technical Orders (TCTO). Survival kits will be maintained by the contractor but all Petroleum, Oil, and Lubricants (POL) will be government-provided (1:2).

CLIN 0002 covers all additional supplies and services provided under CLIN 0001 for flying hours in excess of 12,099. The charge is 59.01 dollars per flying hour in 1980 dollars. Line item 0003 encompasses all charges levied and collected by Foreign Government Custom Offices at the time of part/supplies importation. The contractor shall be reimbursed for these charges once each month or when the aggregated amount exceeds 500 dollars (1:3).

CLIN 0004 allows, upon ACO order, maintenance work over and above that covered by CLIN 0001 and 0002. Work will be negotiated on an as-required basis. CLIN 0005 also is funded as required to cover services necessary for inspection or repair of damage caused by collision with another object on the ground or in flight (1:3).

All aircraft modifications will be covered by CLIN 0006. CLIN 0007 includes all services required for aircraft reassignment such as deactivation of existing beddown bases or establishing a new beddown base. Temporary

Duty (TDY) funding for contractor technicians on aircraft flights is provided via line item 0008. Line item 0009 pays for contractor furnished parts and material used for over and above work. CLIN 0010 encompasses all data and is not separately priced (1:4).

The contractor owns and maintains all ground support equipment. Should the government decide to assume full logistic support of the C-12A aircraft, then the contractor will negotiate for all data, supplies, and spares to be provided to the government. Contractor personnel and dependents will be integrated into station contingency plans and treated as U.S. Government personnel. In a hostile situation, contractor personnel will be on hazardous duty status and subject to U.S. Government authority. The contractor will continue aircraft maintenance and support during hostile situations. Maintenance programs may be modified in this environment but safety of flight will not be compromised. With hostilities, a contingency material support program will be implemented and the contract appropriately modified (1:7-19).

In summary, the twenty-nine C-12A aircraft are maintained by Beech Aerospace Services, Inc. on a worldwide basis. The CLS contract provides for complete aircraft service and maintenance including all organizational, intermediate, and depot level maintenance. The ten line items cover logistic support for a specified flying hour program,

cost on a per flying hour basis for additional hours, custom charges on parts importation, over and above work, collision damage, aircraft modifications, aircraft relocation, contractor technicians TDY, over and above material, and data (1).

T-43

The USAF logistic support contract with Boeing Aerospace Company has an effective date of 1 October 1978. The contract covers supplies and services to support nineteen T-43A Navigator Trainers at Mather AFB. The government will perform organizational level maintenance consisting of removal and replacement of parts, system operational checkout, pre-flight inspection, post-flight inspection, periodic inspection, and phase inspection. Upon agreement with the Boeing COMBS manager, the Air Force may perform both on and off-equipment minor repairs. The contract has ten line items with yearly options extending through 1983 (4).

Line item 0001 is divided into three sub-line items and covers aircraft planned depot maintenance (PDM). Frequency of PDM is dictated by FAA procedures. Air Force personnel will do the flight testing and accompany aircraft to and from the PDM facility. CLIN 0001AA is for aircraft painting and corrosion control on a nose to tail basis. CLIN 0001AB provides for a straight PDM while CLIN 0001AC

includes work for a PDM plus aircraft painting and corrosion control. All three sub-line items are negotiated on an as-required basis. Line item 0002 is also negotiated as the requirement arises. Scheduled or directed engine maintenance, including hot section inspections, is done according to FAA regulations and specifications. Maintenance intervals are specified in the Tech Order (4:1-2).

CLIN 0003 provides for a COMBS at Mather with the contractor holding title to all spare and repair parts. Engines in the built-up quick engine change configuration are part of the contractor's spares. The contractor is responsible for supply support and transportation costs outside Mather. Service bulletin retrofit kits will be stored in the COMBS. Service hours are 5 A.M. to 10 P.M. hours Monday through Friday excluding holidays. Services are on-call at all other times with one hour notification. The Mather AF Deputy Commander for maintenance makes the decisions on part removal and replacement. The government has title to all parts while on the aircraft. Only scheduled engine maintenance is included in this line item. CLIN 0003 has a basic yearly firm fixed price plus a fixed price per flying hour (4:3-5).

The government holds title to the T-43 support equipment at all times. CLIN 0004 is the maintenance and calibration of support equipment as listed. All work must meet FAA standards. The line item is priced for one year.

Line item 0005 allows for three contractor field service personnel; a qualified aircraft general maintenance technician, a qualified avionics systems maintenance technician, and a qualified JT8D-9 engine maintenance technician. Charges are an annual basic fixed price. Also with an annual fixed price is the bench stock provided by CLINs 0006. The bench stock includes high usage expendable type items and the contractor will provide replenishment and inventory. The contractor furnishes all items except military specification soft consumables (4:5-6).

Over and above work is accomplished under CLIN 0007 and 0008. Line item 0008 handles charges for repair or replacement of items due to usage above and beyond fair wear and tear. The contractor is responsible for providing documentation to verify damage was beyond fair wear and tear. Foreign object damage repair is also negotiated under this item. CLIN 007 allows, upon negotiation and ACO direction, supplies and services not within the scope of the other line items. Field team, crash damage repair, and emergency depot level maintenance are examples of work to be done under this line item. All over and above work is separately negotiated as it is authorized by the ACO (4:6-7).

CLIN 0009 is a firm fixed price line item for all technical data requirements. CLIN 0010 allows the ACO to authorize the contractor to furnish or accomplish service bulletin modifications. Procurement and installation

prices will be negotiated as required. All ten line items have annual options through fiscal year 1983. Provision J-3 allows the government to convert to organic support at any time and allow the government to procure all spare parts. Provision J-30 allows for a change of base location with all additional contractor costs to be borne by the government (4:7).

In summary, the T-43 is supported by a CLS contract with Boeing Aerospace Company. The USAF provides organizational level maintenance while the contractor performs intermediate and depot level maintenance. The contract has the following ten line items; PDM, engine maintenance, COMBS operation, support equipment maintenance, field service personnel, bench stock, over and above, over and above fair wear and tear, data, and service bulletin modifications (4).

KC-10

The first USAF KC-10 CLS contract with McDonnell Douglas Corporation became effective 1 January 1978. The AF performs organizational level maintenance except for some periodic inspections, and McDonnell Douglas provides all intermediate and depot level maintenance. The contract has ten major line items, seven of which can be extended yearly out through December 1985. Since this is the first

KC-10 CLS contract, aircraft delivery may vary from the proposed schedule, and line items must take this into account (2).

Line item 0001 includes supplies and services necessary for preoperational planning and coordination. Sub-line items are firm fixed price for three separate years to allow for schedule changes. Tasks include developing an Integrated Support Plan, adviser to the Configuration Control Board, support equipment requirement list, corrosion prevention advisory board, data management, configuration management, preoperational progress report, spares requirement list, and a maintenance task analysis. CLIN 0001 is solely for preoperational planning and will not be part of any follow-on CLS contracts. CLIN 0002 is the price of all data in accordance with the Contract Data Requirements List (DD form 1324) as specified in exhibit A. A lot of this CDRL list is one-time data requirements. This line item will also not be part of any follow-on CLS contract (2:1-3).

CLIN 0003 consists of four sub-line items encompassing all over and above work not within the scope of any other contract options. Unscheduled maintenance, field team crash damage, and emergency heavy level maintenance are covered by CLIN 0003AA. Line item 0003AB provides for all over and above parts withdrawal from the COMBS while CLIN 0003AC allows for scheduled over and above tasks

accomplished at C-check. Line item 0003AD is a catch-all allowing any other work as authorized. All work performed under CLIN 0003 must be authorized by the ACO and a price negotiated (2:4).

Returnable investment material, also called option 1, is charged under CLIN 0004. Sub-line item 0004AA includes returnable investment material initial spares and 0004AB provides for returnable investment material support equipment. Prices are provided in a table by number of aircraft and three separate MOB since the delivery of aircraft may change and different numbers of aircraft for MOB buildup may occur. The three bases will be activated sequentially and any location changes of the proposed MOBs will not cause any price changes. The government will hold title to all material purchased under CLIN 0004 (2:4).

Option 2 or CLIN 0005 encompasses site activation. The three bases in order of activation are Barksdale, Tinker, and McClellan. All work required by the contractor to ready his activities at the base short of operation on a day-to-day basis is covered. While each base activation has a firm fixed price, should the base locations change a price renegotiation will occur (2:4).

CLIN 0006, called option 3, covers maintenance and replenishment material required as a function of flying hours. Since the number of aircraft and utilization rate per aircraft will change as the KC-10 fleet is building up,

the cost per flying hour will change in relation to the total number of flying hours. To account for operational changes Table A-1 was included for pricing calculations (2:4).

TABLE A-1
KC-10 FLYING HOUR CHARGES (2:27)

cum avg flt hr. per a/c per day	.7 to .7999	.8 to .999	1.0 to 1.999	1.2 to 1.3999	1.4 to 1.6999	1.7 to 2.1999	2.2 to 2.7999	2.8 to 3.333
\$ per flt hr per a/c (in 1976) dollars)	587.47	521.05	463.56	426.455	403.26	395.865	400.37	414.735

Line item 0007 provides for COMBS operations, also entitled option 4. This includes supplies and services necessary to operate and maintain COMBS operations. The line item has a firm fixed price per month based on MOB location and the number of aircraft assigned to the MOB during that month (1-4, 5-9, or 10-16 aircraft). Payments to the contractor will be made monthly (2:4).

Remaining data requirements are included in CLIN 0008 but the prices for this data are included in the prices for CLIN 0004 through 0007. CLIN 0009 allows installation of retrofit kits by the contractor. Six specified sub-line items deal with known retrofit kits and are firm

fixed price. CLIN 0010 covers the cost of the delivered retrofit kits prior to installation. Again, six sub-line items specify known retrofit kits (2:4-6).

In summary, the USAF KC-10 aircraft are maintained at intermediate and depot level through a CLS contract with McDonnell Douglas Corporation. Options allow for this support to be extended out to 1985. The contract has ten line items; preoperational planning, data, over and above work, investment material, site activation, maintenance and replenishment materials, COMBS operations, recurring data, retrofit kit installation, and delivered retrofit kits (2).

UV-18B

The USAF UV-18B logistic support contract with Ross Aviation, Inc. for fiscal year 1983 covers maintenance services and supplies for two UV-18B aircraft to fly 1650 hours. The aircraft are based at Peterson AFB while primary missions are flown daily from the USAF Academy airstrip. In addition to cadet parachute training and pilot proficiency, the aircraft will be used for about seven cross-country flights a year. The contractor will perform all organizational, intermediate, and depot level maintenance, pre-flight, post-flight, thru-flight, and periodic inspection. The aircraft must have current FAA airworthiness certificates at all times. The contract has four major line items (6).

Line item 0001 encompasses all labor, parts, and material for required maintenance and services outside of CLIN 0002 and 0004. Manufacturers or FAA temporary repairs will only be accomplished upon ACO approval. The contractor will use specified government facilities at Peterson AFB and the USAF Academy. The contractor owns and is responsible for all support equipment, tools, test equipment, and replacement parts and supplies. The government will provide all fuel and oxygen. On cross-country flights the USAF will provide enroute services. Aircraft security is also a contractor responsibility except when released to an unauthorized crew. The contractor will also maintain maintenance records and submit them to the Air Force. Payments on this line item are made monthly for a firm fixed price. Sub-line item 0001AB and 0001AC cover the same services for optional periods one (fiscal year 1984) and two (fiscal year 1985) (6:104).

CLIN 002 deals with UV-18B engine overhaul/remanufacture. The line item is a firm fixed price per engine overhaul. CLIN 0002AB and 0002AC cover the same services for optional periods, fiscal year 1984 and 1985 respectively. Engines removed for overhaul will be replaced with zero-timed or remanufactured engines by the contractor. All maintenance on these engines will be provided by the contractor. Transportation of overhauled engines is a

contractor responsibility. The contractor will also conduct a spectrometric oil analysis program (6:5).

Line item 0003 provides for the labor in repairing crash/foreign object damage. This does not include damage caused by the contractor on the ground. The line item does include unscheduled maintenance of aircraft when away from their home station as well as any personnel and parts transportation to effect repairs. All work must be approved by the ACO. The line item is a firm price per hour on a cost reimbursable basis. CLIN 0003AB and 0003AC cover labor for repairs in fiscal year 1984 and 1985. The material required to effect these crash/foreign object damage repairs is provided under CLIN 0004. This line item does not cover replacement of condemned recoverable parts and components. Line items 0004AB and 0004AC cover material for fiscal year 1984 and 1985. Line item 0004 has a firm fixed price per year (6:6-7).

Contract clause H-10 sets out price adjustment procedures for variations in the estimated flying hour program of 1650 hours. At the end of each year actual aircraft flying hours are totaled. No adjustment is made if the flying hours are within plus or minus 10 percent of 1650. When the variation in flying hours is greater than 10 percent the fixed price for CLIN 0001 will be adjusted up or down by the same percentage increase or decrease in actual hours flown over 1815 or under 1485 hours. The ACO will

determine any adjustments and change the next month's billing price accordingly (6:57).

In summary, the two USAF UV-18B aircraft are maintained by Ross Aviation, Inc. for an estimated 1650 flying hours a year. All organizational intermediate, and depot level maintenance and ground handling is performed by the contractor. The contract has the following four line items: normal organizational, intermediate, and depot level maintenance excluding engine overhauls; engine overhaul/remanufacture; labor for over and above repairs; and material for over and above repairs. The contract has line items to provide for fiscal year 1984 and 1985 contractor logistic support services (6).

T-41

The USAF T-41C support contract with Doss Aviation, Inc. provides all aircraft maintenance for T-41s assigned to the 557 Flying Training Squadron at the United States Air Force Academy. The contractor provides all organizational, intermediate, and depot level maintenance, ground handling, supplies, pre-flight and post-flight inspections, and POL. All maintenance and servicing will be in accordance with FAA rules and regulations. In addition to FAA minimum acceptable standards, permanent repairs will be made to enhance aircraft utility. The contractor is responsible for supporting daily flying requirements. At no

time will more than eight aircraft be Not Mission Capable Maintenance (NMCM) unless the ACO authorizes a change in this number. Maintenance records will be maintained and open to Air Force inspection (7).

In addition to logistic support at the USAF Academy airstrip, the contractor is responsible for emergency maintenance and refueling at Butts Army Airfield and Peterson AFB when required to return the aircraft to home base. The contractor will assist in any accident investigation as authorized by the ACO or his Quality Assurance Evaluator, at no additional cost to the government. Work not covered by the contract but negotiable includes: support of aircraft not operated from the normal USAF Academy airstrip, use of maintenance support on aircraft not flown, and aircraft maintenance remote from the local flying area. Engine repairs other than organizational and intermediate level will be done by the engine manufacturer (7:4-11).

The contract has nine line items. Line item 0001 encompasses all support for Air Force Academy Cadet Flying Training estimated at 14,920 flying hours for the year. Pilot instructor training is covered by CLIN 0002 and is estimated at 900 hours for the year. CLIN 0003 provides for proficiency, Stan/Evaluation, and miscellaneous military flying not to exceed 1500 flying hours. Six hundred flying hours are anticipated for cross-country flying charged under line item 0004. CLIN 0005 allows for 110 flying hours

for search and rescue training. Functional check flight hours are paid from CLIN 0007, basic-cadet training flights are under CLIN 0008, and the per flying hour charges for cadet weekend flying are specified in CLIN 0009. All these line items have an estimated number of flying hours and a firm fixed price per flying hour charge. Should the actual number of flying hours vary from the estimated flying hours by more than 15 percent (up or down) the contractor and the contracting officer will negotiate a contract change. The contractor will receive flying hour requirements at 3 P.M. on the preceding day. Notification of weekend flying hours will be not later than noon on the preceding Friday (7:2).

CLIN 0005 covers operation and maintenance for required flying hours on line items 0001 through 0005. It is priced on a per month basis, firm fixed price. The actual number of T-41C aircraft to be maintained may vary at the discretion of the government. However, the Air Force will not exceed an average utilization rate of 60 hours per month per aircraft (7:2).

Under provision H-21, the incumbent contractor may be retained for up to four additional years. This is contingent on satisfying past performance, a continued service requirement, contractor capability, and a satisfactory contract negotiation (7:51).

In summary, the T-41C is totally contractor supported including maintenance, POL, and ground handling.

The contract is structured on a firm fixed price per flying hour, differentiated by the type of flying being done. One CLIN covers operation and maintenance for required flying hours. The actual number of T-41s may vary, but provisions are made for a range of flying hours to be flown (7).

C-20A

The USAF C-20A is a new aircraft to be produced and supported under a contract signed 6 June 1983. A total of eleven aircraft will be produced to support worldwide air transportation for high-ranking dignitaries of U.S. and foreign governments. A brief overview of the program schedule is provided followed by a description of applicable CLS coverage (17).

During 1983 three aircraft will be leased from Gulfstream to be delivered in September, October, and November. These aircraft will also be leased in 1984. In 1985 the three leased aircraft will be purchased, although they will not be in the C-20A production configuration. These three aircraft will be modified to production configuration in 1987. In 1986 three more aircraft will be ordered for delivery in 1987 in C-20A configuration. The three aircraft to be ordered in 1987 along with the two aircraft in 1988 will complete the buy of eleven aircraft.

Three aircraft of the eleven will be based in Ramstein while the remaining aircraft will be based at Andrews AFB (17).

E-Systems will provide CLS as a subcontractor to Gulfstream Aerospace. CLS for the leased aircraft is provided under a single line item and includes organizational, intermediate, and depot level maintenance for each year. CLS for production aircraft is provided under one line item with six subline items; COMBS operation, contractor field services, aircraft maintenance support, depot maintenance, logistic data, and peculiar support equipment maintenance (17).

The COMBS operation is similar to the other (C-9A, T-43A, etc.) CLS aircraft which operate under the COMBS concept. C-20A spare parts are stored and exchanged for reparable parts as needed. Spares will be government owned but contractor managed after fiscal year 1985. The facilities for the COMBS are government furnished. The operation is firm fixed priced per year and takes into account the phasing in of additional aircraft. The COMBS will be operated five days a week with two shifts. COMBS personnel are on call twenty-four hours a day should additional support be required (17).

Contractor Field Services (CFS) are provided at Andrews and Ramstein by contractor personnel. Specifically, three CFS personnel will represent skills with avionics,

engines, and airframe. Responsibilities include providing technical assistance, on-the-job and informal classroom training, assistance in troubleshooting, help in performing modifications which are within the capability and capacity of the Main Operating Base (MOB), and participation in test programs if required. Contractor field personnel normally work one shift a day, five days a week, but are also on call for second shift, third shift, and weekend support. A special provision in clause H-33 specifically states that contractor personnel are responsible for continuing their duties in a wartime operation (17).

The sub-line item on CLS aircraft maintenance support prices the off-equipment maintenance. During the first two years when aircraft are leased the contractor performs total organizational, intermediate, and depot level maintenance. Once the Air Force has bought the leased aircraft in 1985 the AF will perform on-equipment maintenance including ground handling, remove and replacement of parts, pre-flight/post-flight inspections, and turnaround maintenance at forward areas. Off-equipment maintenance, done by the contractor, includes scheduled engine overhaul, component repair, modifications as authorized, and the maintaining of a maintenance data collection system. Depot maintenance is separately priced in a sub-line item (17).

The other separately priced items are logistic data, over and above, and peculiar support equipment maintenance. During 1983 and 1984 the contractor owns the peculiar support equipment and spares. However, in 1985 the government will buy all peculiar support equipment and spares, with control retained by the contractor. Common standard stocklisted support equipment will be government furnished and government maintained (17).

The C-20A is a unique program due to the leasing arrangement in the first two years. The CLS portion of the contract is performed by E-Systems, a subcontractor to Gulfstream Aerospace Company, and has six sub-line items; COMBS operation, contractor field services, aircraft maintenance and support, depot maintenance, logistic data, and peculiar support equipment. The government can change operating locations via special provision H-13 and the price to the contractor due to such a change will be negotiable (17).

APPENDIX B
SPECIFIC FUEL CONSUMPTION

Overview

Additional aircraft characteristic data collected on the CLS aircraft is presented along with a short explanation of the usefulness of specific fuel consumption as a variable.

Maximum Specific Fuel Consumption

Maximum specific fuel consumption is the ratio of fuel flow to thrust associated with maximum engine power. Table B-1 summarizes maximum specific fuel consumption. Maximum specific fuel consumption cannot be used as an independent variable due to lack of data for the T-43, UV-18B, T-41C, and the C-20A.

TABLE B-1

MAXIMUM SPECIFIC FUEL CONSUMPTION

maximum specific fuel consumption	E-4	C-9A	C-12A	T-43	KC-10	UV-18B	T-41C	C-20A
	.399	.595	.629	-	.654	-	-	-
References:	(21)	(21)	(10)		(26)			

Intermediate Specific Fuel Consumption

Intermediate specific fuel consumption is defined as the ratio of fuel flow to thrust associated with the engine at the intermediate power. Table B-2 summarizes intermediate specific fuel consumption. Again, with no

TABLE B-2

INTERMEDIATE SPECIFIC FUEL CONSUMPTION

inter- mediate specific fuel consumption	C-4	C-9A	C-12A	T-43	KC-10	UV-18B	T-41C	C-20A
	.380	.570	-	-	.390	-	-	-
References:	(21)	(21)			(26)			

data for the C-12A, T-43, UV-18B, T-41C, and C-20A intermediate specific fuel consumption cannot be used as an independent variable.

Normal Specific Fuel Consumption

Normal specific fuel consumption is defined as the ratio of fuel flow to thrust associated with normal continuous engine power. Table B-3 summarizes normal specific fuel consumption. A lower normal specific fuel consumption can be due to a heavy aircraft, older technology, or fuel inefficiency for a number of design reasons. As normal specific fuel consumption rises, CLS costs are expected to decrease. However, with no data for the C-12A, T-43, UV-18B, and T-41C, normal specific fuel consumption cannot be used as an independent variable.

TABLE B-3

NORMAL SPECIFIC FUEL CONSUMPTION

normal specific fuel consumption	E-4	C-9A	C-12A	T-43	KC-10	UV-18B	T-41C	C-20A
	.372	.555	-	-	.385	-	-	.817
References:	(21)	(21)			(26)			(19)

Explanation

Specific fuel consumption is actually an engine parameter, not an aircraft parameter, and was dropped as an independent variable. In place of specific fuel consumption, nautical miles flown per pound of fuel was used as an independent variable since it is an aircraft parameter and could be calculated the same way for each aircraft.

In addition to having limited data on the specific fuel consumption variables, the sources were unable to adequately define the variable when giving the data. Without a confirmation on the variable's meaning from the data source, the possibility of error is present. The data is presented in this appendix as an explanation of using nautical miles per pound of fuel and for the reader's information.

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